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CONTENTS.

	PAGE.
Cacao Economics	281
Additional Notes on the Seedlessness of Citrus Fruits	283
Prevention of Disease in the Tropics	284
The Cacao Industry of Trinidad	285
Investigations of the Mitscherlich Method in Trinidad	292
Carnauba Wax	298
Recent Investigations on Sugar-cane and Sugar-cane Soils in Trinidad	299
Shall Crops be adapted to Soils or Soils to Crops ?	306
Reviews	307
Sugar Notes	310
Chemical Notes	311
Trend of the Markets	312

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TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, 14, Trinity Square, London, E.C.3, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

CACAO ECONOMICS.

THE Department of Economics of this institution, in common with other College Departments and the officers of the Cacao Research Scheme, has been engaged in research designed ultimately to improve the efficiency of cacao estates. The approach of the agricultural economist to the problem necessarily differs from that of the scientist. Economic research is designed to investigate agriculture as a business while the scientist is concerned with the scientific aspects of agriculture. Scientific discoveries are of little use to the agriculturist until they are translated into agricultural practice. Moreover, the agriculturist is primarily interested in the economic aspect of scientific discoveries; his real problem is not so much how to increase his yields but how to do so *at a profit*. The scientist must, of necessity, consider the economic effects of his scientific discoveries with which the economist is primarily concerned. Here, then, is the common meeting place of the agricultural scientist and economist, and it is the essence of Professor Shephard's investigations that while the various scientists and economists can each contribute something to the welfare of mankind in general and the agriculturist in particular, by working in water-tight compartments, more valuable results will be obtained when they work in co-operation. Instances of the effectiveness of this team work were mentioned in an article by Professor Shephard in an earlier issue of this Journal.* For example, the demarcation of various soil types in the Montserrat District of Trinidad by the Department of Chemistry and Soil Science enabled the Department of Economics to assess more accurately the influence of age of cultivation on yields and profits—results which are of significance to countries other than Trinidad. It was demonstrated that "good" and "bad" Brasso clay soils were synonymous with "young" and "old" cultivation. Again, the detailed examination of fields of various ages showed that damage, diseases and pests accounted for most of the non- and poor-bearing trees and emphasized the fundamental importance of affording special cultural attention to the valuable planting material selected by the Cacao Research botanists.

In this issue Professor Shephard begins a series of articles presenting the results of a financial survey of the cacao industry of Trinidad. This

* *Tropical Agriculture*, Vol. XIII, No. 4.

series is a continuation of the articles* outlining the history of the industry which were published in 1932. "The making of surveys of agriculture is probably as old as civilisation". Writers in all ages have written their impressions of farming in their own and other countries. Many of them have been acute observers and faithful recorders but their surveys suffered the defect of being based, as a rule, on personal observations, and not, as in the case of the modern survey method, on statistical records and analyses. "The normal condition or usual thing", as Warren points out, "is so common as to attract little attention; the exceptions are conspicuous and attract attention and result in exactly the wrong conclusions". The survey conducted by Professor Shephard seeks to substitute comprehensive and reliable data for the limited and, in some cases, exceptional experiences of the individual. The extent to which individual records vary demonstrates the importance and value of an unbiased statistical enquiry. Attention is directed to the difficulty of interpreting the analyses correctly. The economist deals with estates as going concerns and not under laboratory or carefully controlled experimental conditions. His first duty is to discover the *facts of the case* and to expose the strong and weak points of an industry by making as accurate and complete a financial diagnosis as possible.

The information presented in this series of articles is of interest both to public bodies and the individual planter. To the first by providing data regarding the economic organisation and financial condition of the industry, and to the second by revealing those factors associated with profitable and unprofitable estates. The popular conception of yields of 500 lb. per acre, and a cost of production of $10 per bag, have proved erroneous. Yields averaged only 260 lb. per acre and costs of production approached $13 per bag. The range of profits is remarkably wide. For example, one quarter of the estates operated at a loss despite a price exceeding $12 per fanega, but another quarter of the estates could withstand a fall in cacao prices of nearly 50 per cent.

A comparison of estate records according to criteria such as costs of production, location, yields, size, expenditure on and age of cultivation, reveals some of the broad features associated with comparative success or failure. These features serve as a basis for more detailed investigation, the results of which will be presented in a third series of articles. The present survey is not an end in itself but merely a preliminary examination to clarify the issue, and to permit the investigator to concentrate his attention on factors of importance. Thus, the most profitable estates obtained high yields, spent less than the average on cultivation, were about 300 acres in size, consisted of young cultivation, purchased no manures and, in most cases, specialised almost entirely on the production of cacao. Of these characteristics associated with success it is important to ascertain those related as cause and effect. There is little doubt that yields and profits are closely related at any given price level, but this information is of little practical value unless it can be supplemented by the discovery of the factors responsible for differences in yield, and the extent to which conditions on the high yielding estates can be reproduced on the low yielding estates. Differences of yields between estates are not necessarily related to differences in expenditure on cultivation, since some high yielding estates spend very little on cultivation while some low yielding ones spend much above the average on cultivation. Again, the fact that the highest yielding estates do not purchase manures does not necessarily imply that yields were depressed by the application of manures. On the contrary, recent experiments have demonstrated that the application of suitable manures to certain soils doubles yields and in view of these findings there is little doubt that there is likely to be a rapid increase in the purchase of artificial manures when their application can be proved profitable. The outstanding success of young estates suggests that youth of cultivation plays an important part in determining yields and profits, but here again the relationship between age of cultivation and yields can only be established by determining what factors are associated with yield trends, and whether those responsible for declining yields can be counteracted by profitable measures.

The most important factor affecting yields and profits is soil type, a factor closely investigated by the joint efforts of the Departments of Chemistry and Soil Science, and Economics. Professor Shephard will submit in Series III, information regarding the productiveness and profitableness of fields of the same age on different soil types, and of fields of different ages on the same soil type, and conclude the investigation in Series IV in which definite recommendations are made for the rehabilitation of cacao estates in Trinidad. Thus, these articles show that the work of the scientist and economist is complementary and in no way competitive, and that, although appreciable progress has already been made on the road to greater efficiency, much still remains to be done. The Department of Economics has been greatly assisted in its investigations by the readiness with which planters volunteered information, and their cooperation in the work is very much appreciated. The survey has shown, more than ever, the value of keeping records and we would urge that more attention be paid, in future, to this matter in order that the industry may develop on sound business lines.

THE EDITOR requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

* *Tropical Agriculture*, Vol. IX, Nos. 4–11.

ADDITIONAL NOTES ON THE SEEDLESSNESS OF CITRUS FRUITS.

By N. Wright.

I. The Jaffa (Shamouti) Orange.

In a previous article (6) on this subject, reference was made to the work of Oppenheimer (1) in Palestine with the Jaffa orange. Dr. Oppenheimer has since written to correct certain details of his paper, which it will be seen alters to a certain extent the deductions made from his results. He writes as follows :—

"1. On p. 17 of my paper 'On Citrus Fertilization' I erroneously omitted to state that 25 fruits were taken from each of *four* Jaffa orange trees surrounding one of the discussed other citrus varieties. So the figures in Table III and V* are the averages of 100 fruits and not of 25."

"2. In Table III the figures for the Jaffa orange fruits from trees surrounding Sour Orange were erroneously omitted. These figures are 2.27 mean, with 11 maximum, against 1.62 mean, with 7 maximum for the control trees.† "

"3. As mentioned in the last sentence of my paper, the statistical material will be published in full after the experiments will have reached completion."

Until those details are forthcoming, definite *proof* of causation on the part of any one factor would be premature.

"4. As to the importance of the differences in the mean number of seeds in fruits of Jaffa orange trees with and without neighbours of other citrus varieties, I beg to remark that first it seems to me useless to calculate the mean figure for the neighbours of all the different varieties together. It was one of the aims of the study to find out which varieties have an influence on the seed content of the Jaffa orange, and which not, and the said mean figure includes both kinds."

This is taken to refer to my summarisation of his Table III, giving the mean difference in seed number for the whole 16 trees as only 0.75 seed. This value was computed from his data merely to show the extent of variability existing, and its possible statistical insignificance in face of a *maximum* difference in seed number between control and experimental trees (not the same variety) of only 3.78. It is obvious that for a complete statement of the results the mean difference of *each* neighbour variety must be calculated and its statistical reliability assessed.

"On the other hand mean differences of two or three seeds, while surely of no importance for the seedy varieties of orange or for grapefruits are very striking in the almost seedless Jaffa orange, especially if it is taken into account that the maximum of the single figures from which these mean figures were calculated ranged in the significant cases from 7-13, while only 4-9 in the controls. But the fact that the figures for the controls are in some cases much higher than those typical for the Jaffa orange suggests—as mentioned in my paper—the interference of factors other than cross pollination."

No criticism of the significance of the differences observed in Jaffa orange was intended in the statement (p. 4, column 2 of my paper) that they are not comparable with the very large differences found in Trinidad grapefruit. It seems more likely that there are in Trinidad circumstances operating on seed content of the fruit which are absent from Palestine. The discrepancy may of course lie in the fundamental cause of seedlessness differing in the two varieties, but at any rate the two sets of figures could not fairly be subjected to direct comparison.

II. Satsuma Orange.

Dr. Traub, of the United States Department of Agriculture, Washington, has kindly drawn my attention to two series of investigations he has made into fruit quality, in which the number of seeds per fruit was one of the factors under consideration. One of these relates to the Satsuma Orange (3).

Two varieties were studied, the Owari and Kawano Wase. A number of Florida orchards were sampled, a sample being obtained by collecting one fruit from each of 10 trees every week. The number of seeds per fruit of both varieties from all orchards averaged less than one, showing that for all practical purposes the Satsuma is a seedless orange. However, the number of fruit containing seeds was found to vary considerably with locality, and to use Traub's own words "may be dependent upon opportunity for cross fertilization with other species of the genus *Citrus*." If, as Uphof (5) claims, self-pollination in this variety is structurally impossible, then the presence of foreign pollen to stimulate either apogamic seed formation or normal fertilization would seem to be imperative. The degree of female sterility must also be very high.

III. Acid Citrus Fruits.

In the other series of trials (4), Traub and Robinson have examined four varieties of both limes and lemons. The fruit sample here consisted of ten fruits per tree, taken at 14 days intervals. From five, or at least three such samples the data reported in this paper were computed.

The differences in seed content of the lime varieties are not such as to call for any special comment. Tahiti lime is practically seedless—only 9 seeds were found in 170 fruits from various orchards. The remaining three varieties—Lakeland, Key (=West Indian), and Eustis gave averages of 8, 9 and 12 seeds respectively, with no evidence of fluctuations due to external causes or the stock employed.

* These were summarised on p. 4, column 2 of my paper.

† *See* footnote on p. 4 of my paper.

The lemons showed wider variations, *e.g.*, Perrine lemon had from 14-27, and the Meyer lemon 7-18 seeds. From the tables of data in which the authors summarise their results, it is impossible to conclude what the causes of such variations might be ; it seems unlikely that there is a stock effect. The authors make no comments on the figures.

IV. Miscellaneous Crosses.

The effect of various pollens on seed number is discussed by Toxopeus in the course of a recent article (2) in which he reports the preliminary results of breeding rootstocks immune to gummosis (*Phytophthora parasitica*). His crosses consisted of most of the possible combinations between *C. decumana, C. nobilis, C. sinensis, C. Aurantium, C. mitis, C. aurantifolia, C. medica,* Japanese citron (*C. nobilis* hybr.) and rough lemon (*C. Limonia*).

The table following summarises his results so far as seed number is concerned :—

TABLE I.—*Mean Number of Seeds per Fruit from Various Crosses.**

Female Parent.	Male Parent.								
	C. decumana	*C. nobilis*	*C. sinensis*	*C. Aurantium*	*C. aurantifolia*	*C. medica* (citron).	*C. medica* (lemon).	*C. hybridus* (Jap. citron).	*C. hybridus* (Rough lemon).
Citrus decumana	..	99	73	85	44	111	21	43	74
Citrus nobilis ..	..	..	24	..	..	16	15	24	23
Citrus sinensis ..		22	..	21	..	8	3	24	..
Citrus aurantifolia	13	18	17	9	..	..	18	15	18
Citrus medica .. (Lemon)	32	36	26	40	20	..	..	32	..
Citrus hybridus .. (Japanese citron)	10	..	14	19	4	..	8	..	13
Citrus hybridus .. (Rough lemon)	24	36	23	33	13	21	..	20	..

This table shows that there are at least two species which, when used as pollen parents, produce less seed than other species on the same mother plant, namely *C. aurantifolia* (acid limes), and *C. medica*† (lemon variety). Toxopeus suggests that the explanation may lie in the short styles of these two species whose pollen fails to reach the ovary of the other long-styled species. A small set of fruit also results, as would be expected, from crosses employing long-styled female parents and short-styled males.

The table does not indicate that any of the pollen parents have the converse effect of producing more seed than the average, though it is unfortunate that values of seed number from selfed fruit are not available for comparison. None of the varieties chosen were " seedless ", so we have no indication of the possible effect of different pollens on a type like Marsh grapefruit.

In conclusion, it may be of interest to note that in field work of this kind involving a considerable number of flowers for pollination and controlled observation, the author's three Javanese assistants were able over six days to average 227 cross-pollinations and 168 flowers emasculated per day. The hybridization technique followed the usual lines ; the emasculated flowers were bagged and pollinated two days later, using pollen which had been collected in the full-bud stage and stored in desiccators.

* The number of fruits from which the mean has been calculated varies in each case. No statistical issue is involved.

† The specific names here used are those of Toxopeus who does not follow the now most widely accepted system of Swingle. The lemon is referred by Swingle to *C. Limonia*, of which the Rough lemon is a variety. The Japanese citron is of hybrid origin, one of the parents being *C. nobilis*, the other possibly *C. Limonia* var.?

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1. Oppenheimer, C.—" On Citrus Fertilization " *Hadar* VIII, 10 and 11, 1935.
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4. Traub, H. P. and Robinson, R. T.—" Maturity and Quality in Acid Citrus Fruits." *Proc. Florida State Horticultural Soc.* 1935.
5. Uphof, J. C. Th.—(" Notes and Experiments on Citrus varieties VI. The Flower. Part I ") *Gartenbauwissenschaft*, VIII, 1934.
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PREVENTION OF DISEASE IN THE TROPICS.

A meeting of the Industrial Advisory Committee of the Ross Institute (London School of Hygiene and Tropical Medicine) was held on 16th April under the chairmanship of Mr. G. H. Masefield, when reports were received upon the Institute 's activities in India, Ceylon, and South, East, and West Africa. Malaria prevention has received much attention, and instances were given of the value of mosquito control in combating this disease. Other diseases, including yellow fever and the eye-fly pest of India and Ceylon, were also discussed. Allusion was made to the value of reinforced aluminium foil as a heat insulator ; in a tea factory in Ceylon a reduction of temperature of 7°F. at noon in the rolling room had been obtained by its use.—(*Nature*, Vol. CXXXVIII, No. 3480, p. 71, 1936.)

THE CACAO INDUSTRY OF TRINIDAD.

SOME ECONOMIC ASPECTS.

Series II.

A financial survey of estates during the seven years 1923-4 to 1929-30.

By C. Y. Shephard.

INTRODUCTION.

The aim of the present investigation is to discover means of improving the efficiency of Trinidad cacao estates. In the first series of articles the history of the industry was traced from its origin to 1932 (9). In this, the second series, the records of a large number of estates are examined with the object of ascertaining those factors associated with profitable and unprofitable estates which appear worthy of more detailed investigation.* For purposes of convenience the analyses of estate records are presented in five parts :—

I. A detailed account of the average expenditure, yields, cost of production, profits and losses, &c., of all the estates visited.

II. A comparison and contrast of the records of the 'best' and 'worst' estates.

III. A brief examination of the records of different years.

IV. A comparison and contrast of the more important cacao growing districts.

V. An examination of estates grouped according to :—

(*a*) yields per 1,000 pickets.†
(*b*) area under cacao cultivation.
(*c*) expenditure per acre on cultivation.
(*d*) age of cultivation.

* The method employed in collecting the data was described in Series I, Part I (9*a*). A set of 55 tables embodying the principal information was circulated to each planter who assisted in the investigation. (Nine of the more important tables are included in the present series of articles). These tables have already served the function of providing each planter with criteria by which he could distinguish and perhaps rectify excessive or inadequate expenditure on particular items.

† Picket=tree site. See Glossary.

PART I.—DETAILED EXPENDITURE, &c., OF ALL ESTATES VISITED.

(*See* Table I and Figs. I-VI (1).)

The records here analysed were obtained from 126 estates with a total of 32,220 acres under cacao, and cover the period 1923-4 to 1929-30. The average annual expenditure per acre on all items is given in Trinidad currency and sterling. The composition of each item and the method of conducting the principal operations are explained to permit an appreciation of those changes involved by the methods of rehabilitating cacao estates in Trinidad which will be recommended in Series IV. The average annual expenditure per acre on cacao cultivation during the period 1923-4 to 1929-30 amounted to \$20.22 (£4 4*s.* 3*d.*) and was made up in the following manner :—

Management and Supervision (Item 1).*

The expenditure on management and supervision amounted to \$4.91 (£1 0*s.* 5½*d.*) per acre and represented no less than 26 per cent. of the total. The salaries of managers and overseers and the wages of drivers account for most of this expenditure, the remainder consisting of bonuses, allowances (*e.g.*, for servants and travelling) and other small items. Despite the fact that salaries are supplemented by free housing, fruits, vegetables, firewood and other allowances and perquisites, they are too low to attract suitable new candidates. The manager usually decides the nature and extent of the work which is carried out by gangs of labourers under the immediate supervision of a driver. The proportion of resident to non-resident managers has diminished since the introduction of the motor-car. In some instances a 'visiting planting attorney' exercises general control over a number of scattered estates each in charge of a resident overseer. Few owners reside on or manage their estates.

High prices of cacao, low wages, good yields and abundant credit, which were characteristic of the 'golden age' (1870-1920) of the industry, were reflected in methods of management. A systematic policy of estate maintenance and extension could be pursued without necessitating the building up of reserves. The entire profits were usually withdrawn year by year. The use of estate records as an aid to management appeared an unnecessary refinement. The system of book-keeping remained most elementary, and seldom extended beyond a pay list and a general abstract of expenditure. Few planters recorded the yields of individual fields, and even today only two maintain a system of field costings.

* The item numbers correspond to those used in the statistical tables circulated to planters and to those here printed as Tables I to IX.

(1) Table I and Figures I–VI will be published with Part II in our next issue. The list of References and Glossary will be published with the General Summary and Conclusions.

Half a century of comfortable security left the industry ill-equipped to face the blast of post-war depression. Traditional methods of management were never called into question. The reorganisation forced upon the Trinidad sugar industry by the depression during the latter part of the 19th century, and the skilful use made of cost accounts as an aid to management in post-war years, have no counterpart in the cacao industry. During the period under review (1923-4 to 1929-30), the price of cacao was high enough to permit most planters to maintain their cultivation in the manner they considered most efficient. The low prices of cacao realised from 1930-31 to 1935-36 have compelled a critical examination of the traditional methods of producing cacao, and have quickened the interest of the planting community in scientific and economic research.

Cultivation (Items 2-9) (*See* FIG. III).

Methods of cultivation are of especial interest because of all estate expenditure only that on cultivation is capable of influencing yields, and modifications of the traditional methods must constitute an important part of any scheme for the rehabilitation of estates. The standard of cultivation in Trinidad stands midway between the intensive orchard cultivation of Grenada, and the casual methods of the Gold Coast and Nigeria. Yields per acre in Grenada and West Africa are probably at least twice those of Trinidad, and it is a matter of considerable importance to the planter to know whether he should emulate the methods of the one or the other or neither in his search for improved efficiency. Data relating to the profitableness of the industry in Grenada and West Africa are lacking, but that deficiency is here remedied for Trinidad. For comparative purposes the daily wage rates may be accepted as 45 cents (1*s.* 10½*d.*) for men, and 30 cents (1*s.* 3*d.*) for women. The total expenditure on cultivation per acre for labour alone (*i.e.*, excluding supervision and materials) averaged $7.25 (£1. 10*s.* 2½*d.*), and accounted for 36 per cent. of the total expenditure on cacao. The principal items are described below.

Cutlassing and Weeding (Item 4).

'Cutlassing and weeding' is the most costly of the items of cultivation, and accounts for $3.06 (12*s.* 9*d.*) per acre, or 42 per cent. of the total expenditure on cultivation. The principal operation, known as cutlassing, is the cutting or 'brushing' of the weed growth two, three or four times a year, to prevent interference with the cacao trees, and to facilitate the collection of harvested pods from the ground. The vegetable matter is left as a mulch, and 'clean weeding' is invariably avoided. Cutlassing is allocated almost invariably by the task (*e.g.*, 100 pickets), or the job (*e.g.*, a field), the task rate ranging from about 30 cents (1*s.* 3*d.*) to 70 cents (2*s.* 11*d.*) according to the amount of work involved. Particularly troublesome weeds are uprooted. The inexpensive operation of ring-weeding, termed locally 'arrondeering', merits special attention. It was customary for labourers (usually women or children) to precede the cutlassers in the field, and hand-weed a small area around the base of each tree, paying particular attention to each 'supply'. 'Arrondeering' not only assisted each young cacao tree in its competition with weeds but, by exposing its location, also enabled the cutlasser to avoid injuring it. Reductions in the expenditure on cutlassing and weeding have been effected since 1929-30 by reducing the frequency of 'brushing', and neglecting 'arrondeering'. Little effort has been made to discover a perennial leguminous cover crop capable of smothering weeds, but free from the inclination to climb the cacao trees, and low enough in growth to reveal harvested cacao pods. Such a crop would effect appreciable economy in the cost of cultivation in addition to conferring other benefits. *Vigna oligosperma* (or *Dolicos Hosei*) is used extensively on San Thomé cacao estates, and has been tried on one Trinidad estate where it displayed too high and thick a habit of growth. The neglect of 'arrondeering' has been attended on many estates by the wounding of an alarming percentage of the young cacao 'supplies' to an extent which prevents their development into high-bearing trees. 'Arrondeering' of young supplies should be regarded as an indispensable operation.

Trimming and Pruning (Item 3).

Cacao Trees.—The expenditure on trimming and pruning ranks next to cutlassing and weeding in amount, averaging $1.85 (7*s.* 8½*d.*) per acre, and representing 25 per cent. of the total cultivation expenses. The principal operation is a light annual trimming, or a more severe pruning at intervals of three or four years, of the cacao trees. The systematic removal of redundant suckers from the cacao trees constitutes a minor operation which is sometimes combined with other work. Most planters attached considerable importance to trimming and pruning as an aid to the development of a well-balanced and highly productive cacao tree. The work was almost invariably allocated to labourers working by the day under very close supervision, and every wound was dressed with some more or less effective fungicide. Since 1929-30 trimming and pruning have been conducted at much longer intervals than formerly and, as an additional means of reducing expenditure, the work has been assigned to labourers working by the task or job. Each tree requires separate consideration, and the operation demands a high degree of skill and patience. A labourer whose remuneration varies with the number of trees pruned tends to be too drastic, and oftentimes careless, in the use of the knife, and he may inflict serious injury to the tree. Wounds now receive but scant attention. It appears false economy to entrust trimming and pruning to labourers working by the task or job unless they happen to be exceptionally skilful and conscientious men.

Shade Trees.—Expenditure is rarely incurred on controlling the growth of trees used to provide shade for cacao. The shade trees consist almost entirely of either *Erythrina umbrosa* ('Anauca') or *Erythrina velutina* ('Bocaré'), both locally known as Immortels. Many other trees have been tried and abandoned, notably *Castilloa elastica*. The *Anauca*, or 'hill-shade', grows to a height exceeding 100 feet in suitable conditions and carries a small canopy. The Bocaré, 'water-immortel' or 'shade of the plains', has a lower and more spreading habit of growth and a larger canopy. Most planters grow the Bocaré only on areas where the Anauca will not thrive. Shade trees were planted between alternate rows of cacao (*i.e.*, 24 ft. or 28 ft. apart according to the distance of the cacao trees), but this spacing is now considered to provide too dense a shade. In a few instances redundant trees have been cut out, but there has been little attempt to control the height of shade trees. A single giant Immortel is capable of injuring as many as 16 cacao trees when it falls to the ground, and most of the patches of poor yield discovered on the good soils examined in the present investigations were associated with fallen shade trees. It is highly desirable that Immortels should be grown in rotation, regularly pruned and eventually removed before attaining a size capable of inflicting severe damage to the cacao tree. *Erythrina lithosperma*, or Dadap, might be tried as a shade tree because it is spineless, and can be climbed by the labourer without fear of injury for the purpose of pruning. The removal of the existing giant Immortels without causing excessive damage to the cacao trees presents a most difficult problem.

Draining and Round-Ridging (Item 5).

Drainage involved an average expenditure of 93 cents (3*s.* 10½*d.*) per acre, or 13 per cent. of the total cost of cultivation. This item embraces all operations connected with digging and cleaning main and subsidiary drains, and spreading the earth over the beds to facilitate the gentle run-off of surplus water. The work is performed efficiently by the task or job. The expenditure per acre varied appreciably from estate to estate according to the configuration of the ground, the nature of the soil, rainfall, and the resources and ideas of owners and managers. Most managers adopted some definite policy such as attending to the drainage requirements of one-quarter of the estate each year. Since 1929-30 drainage has been sadly neglected on most estates as a temporary means of reducing expenditure.

'Supplying' Cacao and Shade Trees (Item 2).

The supplying of cacao and shade plants to replace those missing cost only 68 cents (2*s.* 10*d.*) per acre, and accounted for nine per cent. of the total expenditure on cultivation. Despite its modest cost this item must be regarded as one of great importance. An injured cacao tree is usually replaced by encouraging the growth of a chupon or sucker from its base. The parent tree may be cut away when the sucker commences to fruit. New plants were supplied to replace dead and missing trees. The traditional estate practice was to 'supply' every 'missing' tree (or unoccupied site) each year. This simple policy had the merit of preventing the accumulation of large numbers of blank spaces but when, as was often the case, no special treatment was accorded the young plants, the practice degenerated into an annual replacement of dead or dying 'supplies'. Since 1929-30 many planters have gladly, and wisely, abandoned the old method of 'supplying' their cacao fields, but few, unfortunately, have adopted the alternative of concentrating their supplies on areas which have been rendered suitable for their growth. There is no difficulty in raising to maturity supplies planted in good, well-drained, soil, provided they are given special attention. Beetles (*Steirastoma depressum*), falling Immortels, Witchbroom* (*Marasmius perniciosus*), deer and other agencies render some casualties inevitable, but the number should not be sufficient to warrant the abandonment of supplying. A field which is never supplied is a wasting asset. A systematic policy of supplying must form a vital part of any scheme for the rehabilitation of cacao estates.

Few planters exercised any discrimination in the selection of planting material. Seedlings raised in beds, bamboo pots, or baskets were almost invariably used. Many writers, notably Pound (7) in recent years, have drawn attention to the amazing variation from tree to tree in the number of pods required to produce 1 lb. of dry cacao, the number of beans per pod, and the weight of individual beans. Pound's revelations have led to the more extensive use of beans from selected trees for propagation purposes. Vegetative methods of propagation remain in the experimental stage.

The development of an export trade in bananas in the past two years may have an important reaction upon the attitude towards supplying cacao fields. Bananas, balisier (*Heliconia bihai*), tannias (*Colocasia antiqu*), cassava (*Manihot utilissima*) and other plants were used as 'ground' shade for young cacao supplies. The variety of banana and the size of the bunch were of little consequence in the absence of a market. Attempts to grow the Gros Michel banana between rows of well established cacao trees are certain to prove unprofitable, but the removal of low bearing and unprofitable cacao trees will furnish patches in which bananas can be grown successfully for two or three years while the young cacao supplies are developing. Recent experience suggests that in suitable conditions the profit from bananas may more than cover the cost of rehabilitating the cacao cultivation.

The expenditure on supplying shade trees has been insignificant. The overhead shade on most estates is considered too dense and replanting has been confined to patches in which large numbers of Immortels have fallen.

* More correctly, but less euphoniously 'Witches' Broom'. (See reference. 3.)

Manuring (Item 6).

It is surprising to find that thousands of acres of cacao in Trinidad, some of which have been in cultivation for more than a century, have never been manured. The expenditure on applying manure, burying vegetable refuse ('trenching'), mulching, spreading or burying rotted cacao shells, &c., averaged the insignificant amount of 38 cents (1*s.* 7*d.*) per acre, or five per cent. of the total cultivation costs. To this expenditure should be added eight cents (4*d.*) per acre representing the cost of purchased manures (item 15). Most of the expenditure is incurred in transferring small quantities of stable manure to nearby fields. The majority of the few experiments with artificial manures conducted by planters gave disappointing results. The important investigations conducted by Hardy, McDonald (6) and the Department of Agriculture into the manurial requirements of various types of cacao soils will probably result in the extensive use of fertilisers. Cacao planters in Grenada have for many years made heavy applications of organic and inorganic manures to their fields.

Control of Pests and Diseases (Item 7).

Expenditure on specific measures for the control of the impressive number of pests and diseases amounted to only 21 cents (10½*d.*) per acre, or three per cent. of the total expenditure on cultivation. This item includes the collection of insects (*e.g.* beetles); excision of diseased material (*e.g.* canker); shooting, poisoning or trapping squirrels, deer, rats, &c.; and spraying (rarely practised), but does not embrace those cultural operations such as drainage, pruning, manuring, &c., which by improving physiological conditions and the vigour of the trees, reduce the damage caused by pests and diseases.

Diseases (3).—Pod rot, caused by the fungus *Phytophthora palmivora* Butler, is responsible for greater losses of crop than any single pest or other disease. The same fungus is responsible for canker which causes the death of many branches and trees. There are numerous root, stem and pod diseases which are of little consequence except in localised areas. Special mention must be made of the serious menace to the industry resulting from the presence of Witchbroom. It was first recorded in Trinidad in May 1928, and although by the end of the period under review (1923-4 to 1929-30) only a small portion of the total acreage had become infected, and the expenditure on methods of control was negligible except on a few estates, the grave consequences of the disease were soon appreciated. The disease is caused by *Marasmius perniciosus*. The spore infects the growing point of a vegetative shoot, and results in a short thick growth or 'Witches' Broom' which turns brown from the base upwards and eventually dies. The mushroom fructifications of the fungus are produced on the dead brooms under favourable conditions of moisture. The dangers most feared are the infection of the cacao pods, which is accompanied by a loss of beans ranging from none to 100 per cent. depending upon the length of time between infection and maturity of the pod, and the infection of fruit cushions which are rendered barren. Control measures consist of the removal and burning or burying of all infected material. This disease is now responsible for more expenditure than any pest or other disease. The low prices obtained for cacao since 1929-30 have prevented all but a few estates from exercising effective measures of control, and the disease has spread to every important cacao growing district in Trinidad, and has increased alarmingly in intensity. Many responsible individuals consider the entire industry doomed but the writer does not share this view. A large section of the industry, which the writer estimated at one third of the total area (9*e*), cannot survive even if entirely free from Witchbroom. This disease will seal the fate of a large additional acreage. Measures which result in increasing the yield per acre will automatically reduce the cost per bag of cacao of controlling the disease. Efforts are now being made to discover in Trinidad, or elsewhere, strains of cacao resistant to the disease. The multiplication of this planting material and its development to the bearing stage will occupy a period of at least five years from the time it first becomes available, and in the meantime measures tending to increase yields per acre offer one of the most promising means of enabling the industry to combat the disease.

Pests (2).—The principal insect pests of cacao in Trinidad are cacao thrips (*Selenothrips rubrocinctus* Giard), and the cacao beetle (*Steirastoma depressum*). Thrips feed upon, and deposit their eggs in, the leaves of the cacao tree. A severe infestation may result in defoliation of the tree and serious loss of crop. They also attack and discolour cacao pods but do not injure the beans. Spraying with Bordeaux Mixture is effective but uneconomical. Cultivation on soils deficient in potash is especially liable to attack. A parasite (*Dasyscapus parvipennis* Gahan), was introduced from the Gold Coast in 1935, and has since been liberated in large numbers (1). The cacao beetle lays its eggs in or on the bark of the tree. The larva tunnels its way through the wood and may cause injuries sufficient to kill a branch. 'Supplies' attacked at the 'jorquette' (fork) may suffer irreparable damage. Control measures consist of excising injured portions, collecting and trapping adult beetles, and providing ground and overhead shade. Many other insect pests are known, but they are seldom of any economic significance.

Miscellaneous Cultivation (Item 8).

The expenditure on operations which cannot be grouped conveniently under the principal headings amounted to only 14 cents (7*d.*) per acre, or two per cent. of the total expenditure on cultivation. Crops intercultivated with cacao absorbed most of this expenditure.

Reaping (Item 10). (*See* Figs. I and II).

Reaping cost an average of $2.52 (10*s.* 6*d.*) per acre, equivalent to $1.60 (6*s.* 8*d.*) per bag (165 lb.) of dry cacao, and representing 12 per cent. of the total expenditure on cacao. All operations from the severance of the pods from the tree to the delivery of the wet cacao (or raw beans) to the fermentary are included in this item. Pods borne on the trunk and lower branches are removed by the cutlass, while those on the upper branches are reached by a 'picker' attached to a long slender bamboo rod. The 'picker' has two cutting edges which permit the labourer to sever the stalk by either pulling or pushing*. Labourers engaged in picking cacao, who are known as 'rods', were generally employed by the day under close supervision. Many attempts were made to devise an efficient 'picker' which would prevent the labourer from injuring the fruit cushions. Since 1929-30 most planters have reduced the cost of picking by allocating the work by the task or, less frequently, the job. Two important drawbacks may accompany this change: the labourer may inflict serious injury to the fruit cushion, and he is encouraged to include immature pods and to neglect ripe but less accessible ones, in his haste to complete his task. Further saving has been sought by conducting picking 'rounds' of the estate at longer intervals. These economy measures have resulted in the reaping of an undesirably large percentage of unripe and overripe pods. Unripe beans, although fermented for the usual period, possess a hard, purplish 'break' when dried, and are classified commercially as underfermented. Overripe beans,on the other hand, rapidly undergo the changes associated with fermentation, and assume a dull, lifeless 'break' classified as overfermented. A germinated bean is now occasionally found in Trinidad cacao. 'Rods', or cacao pickers, should be employed by the day unless they are highly skilled and exceptionally conscientious.

The cacao pods are collected from the ground, built into conveniently situated and sized heaps, and broken by a labourer using a knife or shortened cutlass having a fairly blunt edge. The 'breaker' strikes the pod transversely, lifts the adhering pod to the left hand and wrenches it into two sections which are thrown to the 'extractors'.† Women or children extract the beans from the broken pods, either by the fingers or with a wooden spatula, and place them in baskets or boxes. The placenta (or "guts") and usually the diseased and inferior beans, are removed at this stage. The baskets or boxes of 'wet' cacao are slung, pannier fashion, on a donkey or mule, and 'crooked' to the 'sweat' boxes. On some properties, especially the small ones, the cacao is 'headed' from the fields, while on a few of the large ones it is carted. Gathering, heaping and breaking the pods and extracting the beans can be performed efficiently by the task or job. The labourer who accompanies the 'crook' animal is paid by the day.

* For illustrations of cacao 'pickers' see reference (5), p. 132.

† In West Africa many farmers have adopted more laborious methods of breaking the pods, *e.g.*, (i) banging two pods together, (ii) striking the pod with a mallet, or (iii) cutting the pod longitudinally. (See reference 10.)

Manufacture (Item 11).

Fermentation.—The expenditure on manufacture averaged 86 cents (3*s.* 7*d.*) per acre, equivalent to 55 cents (2*s.* 3½*d.*) per bag (165 lb.) of dry cacao, and representing four per cent. of the total expenditure on cacao. This item includes all labour for sweating, drying and bagging the cacao. The battery of sweat boxes is housed in a wooden building equipped with hinged half-doors which can be opened or closed to control ventilation. The boxes are made of wood, such as cypre (*Cordia alliodora*) or cedar (*Cedrela mexicana*), or occasionally of concrete, and vary considerably in dimensions, but 4ft. by 4ft. by 4ft. is a common size. In many cases the front, and the sides dividing adjoining boxes, are composed of separate boards—fitting into grooved uprights—which can be removed in order to facilitate the charging and discharging of cacao. The bottom boards are either separated by spaces of about ¼ in. or are perforated to permit the passage of the mucilage or "sweatings" to the drain below. Banana leaves are used to line the boxes and to cover the wet cacao. The wet cacao is transferred from box to box about every two days until fermentation is completed in six to eight days.

Drying.—The curing of cacao is completed by drying the fermented beans in the sun. Very few estates use artificial dryers. The standard drying shed in Trinidad consists of a raised wooden floor measuring 60 ft. by 20 ft., covered by a light galvanised iron roof divided into two sections which can be pushed outwards along rails to expose the floor to the sun. The usual cost of a shed was $1,200 (£250). The length of the shed runs due North in order to reduce to a minimum shadows thrown by the roof. The beans are removed from the sweat boxes and spread two to three inches thick on a clean dry floor. During the first two days a labourer, who has sacking tied to his feet, turns the beans at frequent intervals, throwing them into ridges and leaving lines of floor exposed to the sun as he shuffles from end to end of the shed. The operation is repeated by breaking the old ridges and throwing up new ones on the dry portions of the floor. The process is continued by forming ridges across the floor. During this early stage the beans may be heaped at night in order to complete fermentation. During later stages the cacao is raked with a wooden instrument ('rabot') into small heaps, or thick ridges, which are repeatedly broken down and remade. After four or five days exposure to the sun a gang of labourers is employed for a short time to 'dance' or polish the beans with their feet.

Drying is usually completed in another one or two days, but in wet or cloudy weather it may be prolonged to 14 days. On most estates, waste and foreign material is removed by hand during and/or immediately after drying, a process known as 'garbling'. A few estates use a hand-operated mechanical sizing machine to grade their beans. The cacao is then bagged and placed in the store pending despatch to the market. The beans lose approximately 60 per cent. of their weight during fermentation and drying.

The curing of cacao is performed more efficiently in Trinidad than in Ecuador or West Africa (10), but is not so uniform as in Grenada. Nevertheless, Ecuador enjoys a premium in price because of its superior type of bean, while Grenada obtains a lower price by reason of its inferior beans. West African cacao is inferior both in respect of type of cacao, and methods of preparation.

Live-Stock (Item 12).

The expenditure on live-stock averaged $1.09 (4*s.* 6½*d.*) per acre, representing five per cent. of the total expenditure on cacao. Mules or donkeys are used to 'crook' the wet cacao from the field to the fermentary. Large estates may, in addition, maintain one or more riding ponies, but small properties seldom possess any working animals. The small quantities of manure obtained are applied to nearby fields and cacao 'supplies'. The daily wages of the stock-keeper constitutes the principal item, but any expenditure on the maintenance of pastures, purchase of stock, veterinary fees, medicines, or the wages of the groom, farrier, clipper and water-carrier, is also included. An additional outlay of 43 cents (1*s.* 9½*d.*) per acre was incurred in the purchase of foodstuffs (item 16), but it is probable that a small additional sum for foodstuffs is included under 'other estate supplies' (item 17).

Buildings (Item 13).

Expenditure on the erection and repair, cleaning and insurance of buildings was equivalent to 93 cents (3*s.* 10½*d.*) per acre, or five per cent. of the total. Most estates provide dwelling houses, rent free, for the manager and overseer. A varying percentage of the labour force is housed in wooden buildings, known as barracks, which are sub-divided into rooms with minimum dimensions of 10 ft. by 12 ft. (8). Each compartment has a covered gallery or verandah, 4 ft. to 6 ft. in width, intended for the purposes of cooking, storing fire-wood, &c. Barracks were originally designed to comply with the requirements of the indentured immigration ordinance but, since the termination of the indenture system in 1917, labourers have shown a growing inclination to erect or rent independent huts or cottages. Some estate owners have had the foresight to encourage this movement by offering suitable house-sites on favourable terms. A fermentary, drying-sheds, a storeroom and stables complete the necessary buildings. Few estates found it necessary to erect new buildings during 1923-4 to 1929-30 because most had already attained their maximum development.

Taxes (Item 14).

Taxes represented a charge of 62 cents (2*s.* 7*d.*) per acre of cacao, or three per cent. of the total expenditure. The largest item is a tax of 24 cents (1*s.*) on every acre of land. House, wheel and motor-car taxes, and gun, dog and driving licences are also included. Income tax is not included, but customs and excise duties on imported supplies, petrol, &c., are included in the purchase price.

Estate Supplies (Items 15 to 18).

An outlay of $1.30 (5*s.* 5*d.*) per acre, representing six per cent. of the total, was incurred on estate supplies. The purchase of manures accounted for a mere eight cents (4*d.*) (item 15), and foodstuffs for 43 cents (1*s.* 9½*d.*) (item 16), but it is probable that a small additional expenditure on these items is included in 'other estate supplies' (item 17), on which 79 cents (3*s.* 3½*d.*) was spent. Cacao bags, and many miscellaneous items such as cacao baskets, crooks, cement, timber, harness, tools, nails, twine, &c., constitute 'other estate supplies'.

Miscellaneous (Item 19).

Miscellaneous items of expenditure, such as donations to charitable and other institutions, legal fees, &c., amounted to only 25 cents (1*s.* 0½*d.*) per acre, or one per cent. of the total.

Roads and Bridges (Item 20).

The construction, maintenance, and repair of roads and bridges cost 37 cents (1*s.* 6½*d.*) per acre, or two per cent. of the total. Wheeled transport is seldom used within a cacao estate. The 'crook' animals use paths along the borders of fields or between the cacao trees. In some cases the paths are roughly metalled, and cheaply constructed bridges are used for crossing drains, ravines, streams, rivers, &c.

Total Expenditure &c. (Items 22 to 26).

The gross expenditure on cacao totalled $20.10 (£4. 3*s.* 9*d.*) per acre, representing a cost of $12.73 (£2. 13*s.* 0½*d.*) per bag (165 lb.) of cacao. A revenue of 44 cents (1*s.* 10*d.*) per acre, which is equivalent to 28 cents (1*s.* 2*d.*) per bag of cacao, was obtained from crops, principally coffee, grown along the borders of cacao fields or between the cacao trees. The expenditure on these inter-cultivated crops could not be separated from that on cacao and the revenue derived from them is therefore deducted from the expenditure on cacao, which is consequently reduced to $19.66 (£4 1*s.* 11*d.*) per acre, or $12.45 (£2. 11*s.* 10½*d.*) per bag of cacao.* The cost of transporting cacao from the estate to the merchant's store in Port-of-Spain, or occasionally a nearer market, amounted to 36 cents (1*s.* 6*d.*) per bag, or 56 cents (2*s.* 4*d.*) per acre. At one time the bulk of the cacao was carted, crooked or headed to the

nearest railway station or shipping depôt, delivered to Port-of-Spain, and then taken to the merchant's store in hired carts. Today, motor-lorries collect most of the cacao at the estate and deliver it to the purchaser without break of load. The total cost of producing cacao and delivering it to the merchant's store amounted to $12.81 (£2 13s. 4½d.) per bag, or $20.22 (£4 4s. 3d.) per acre. It may be noted that the generally accepted estimate of cost was $10.00 (£2 1s. 8d.) per bag. Since 1929-30, expenditure has been severely reduced by increasing the size of tasks and by omitting operations hitherto considered essential to the maintenance of efficiency. This policy of neglect can be regarded only as a temporary palliative, and must inevitably result in reduced yields. A more permanent solution must be sought along the lines of improved efficiency.

Revenue from and Profit on Cacao (Items 29-31) (*See* Figs IV to VI).

The average price of cacao at store Port-of-Spain from 1923-4 to 1929-30 was $12.32 (£2 11s. 4d.) per fanega (110 lb.), or $18.48 (£3 17s. 0d.) per bag, giving a revenue from cacao of $29.17 (£6 1s. 6½d.) per acre. Hence, the estates examined were able to show a profit of $3.78 (15s. 9d.) per fanega, $5.67 (£1 3s. 7½d.) per bag, or $8.95 (£1 17s. 3½d.) per acre. These profits were appreciably less than those anticipated, the difference being accounted for primarily by the fact that yields were much lower than generally estimated. The estates examined returned an average yield of 5.69 bags per 1,000 pickets, which is equivalent to 1.58 bags or 260 lb. per acre, and 0.94 lb. per picket. Gilbert's subsequent survey (4), covering every cacao property in Trinidad, showed an almost identical yield. This yield falls far short of the generally accepted estimate of 10 bags per 1,000 pickets, or, say, 495 lb. per acre, and it is surprising to find that trees producing less than 12 pods of cacao per annum should be capable of earning profits. During the years 1930-31 to 1935-36 the price of cacao averaged only $6.67 (£1 7s. 9½d.) per fanega, or $10.00 (£2 1s. 8d.) per bag. The further fall in yields consequent upon neglected cultivation, and the impossibility of devoting sufficient funds for the control of Witchbroom have created a desperate situation.

Other Expenditure and Revenue (Items 32 and 33).

The estates examined spent 89 per cent. of their total expenditure on cacao, and derived 89 per cent. of their total revenue from that one source. Cacao growing had proved so profitable from 1870 to 1920 that, on land where it could be grown, no other crop was allowed to compete. Many estates possessed small areas of limes, coconuts, coffee, grapefruit, tonca beans, oranges, corn, &c., but it was not until the dramatic fall of cacao prices during 1920-21 shook the confidence of the cacao planter that he gave serious attention to the possibilities of alternative or even subsidiary crops. The depression in the price of nearly every agricultural commodity since 1929-30 has weakened the hope that a greater diversification of crops would secure greater financial stability. The morale of the cacao planting community has been completely shattered.

Interest (Items 38 and 39).

The estates paid in interest, principally on mortgages, $2.00 (8s. 4d.) for every acre of cacao, or $1.26 (5s. 3d.) for each bag of cacao produced. The important part played by mortgages in the establishment and expansion of estates has already been described (9d.). From 1923-4 to 1929-30 few estates experienced difficulty in meeting interest charges, but since then payments by most estates have fallen heavily into arrears. The attempts to compromise between the needs of the owner, the rights of the mortgagee, and the requirements of the estate have, in most cases, impaired the efficiency of the estate, and thereby the ultimate interests of the owner and mortgagee. Few mortgages have been foreclosed, but the existence of this possibility has a disheartening effect on estate owners. The re-organisation of sugar estates into companies with ordinary shares assisted the industry to weather the depressions of the latter part of the 19th century and of the 20th century, and would probably confer similar benefits on the cacao industry. Interest on capital either to owner or mortgagee would be paid only from current or accumulated profits, and not, as in recent years, at the expense of the efficiency of the cacao estate.

Summary.

Details of the average annual expenditure of 126 Trinidad cacao estates during the period 1923-4 to 1929-30 are given to show the manner in which they are cultivated. Mention is made of the changes in practice necessitated by the low cacao prices obtained since 1929-30. The records show that, despite yields being less than half those obtained in Grenada and West Africa, high prices enabled the industry to operate at a small profit. The estates derive 90 per cent. of their income from cacao. The drastic fall in cacao prices since 1929-30 has reduced the industry to a parlous state. The depression has been aggravated by the rapid spread of Witchbroom disease and the existence of heavy mortgages. Estates are involved in a vicious circle of heavy losses, neglected cultivation, intensified Witchbroom infection and falling yields. There is, however, considerable variation in the efficiency of different estates, and in Part II the records of estates with the lowest costs of production are compared and contrasted with those having the highest costs of production.

(*To be Continued.*)

* The deduction of the revenue from inter-cultivated crops is not shown in Figs. I and II.

INVESTIGATIONS OF THE MITSCHERLICH METHOD IN TRINIDAD.

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(I) Foreword.

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Mainly with the idea of providing subjects for practical work for Post Graduate students, investigations of various aspects of the Mitscherlich pot culture method for assessing the nutrient status of soils, and for prescribing manurial treatments with the object of increasing their productivity, were inaugurated at the College with simple apparatus in November, 1932. They have been continued intermittently up to the present time, and further work is being planned for the future.

The preliminary experiments were undertaken during the first year (November, 1932 to May, 1933) by Messrs. O. S. Milburn and A. V. Coombs, whose main aim was to test various tropical plants in respect of their suitability as "indicators". At the suggestion of Hawaiian authorities, Sudan Grass was included among the plants tested; its performance seemed to offer great possibilities, and this indicator has figured largely in all subsequent experiments at the College. The numerical results obtained with different local soils, however, were very inconsistent.

During the second year (December, 1933 to May, 1934), Sudan Grass was further tested by Messrs. J. R. Miller and H. K. Ashby, who gave particular attention to the evaluation of the Mitscherlich "effect factors" for the three chief nutrient elements, nitrogen, phosphorus and potassium, which appeared not to be the same for Sudan Grass as for the standard Oats employed as indicator by Mitscherlich in Germany.

The third year's work (December, 1934 to May, 1935) was undertaken by Messrs. C. W. R. McCreary and G. E. Tidbury, who attempted to obtain accurate growth curves for Sudan Grass planted in an infertile soil treated separately with phosphate and potash. The data obtained demonstrated that, although Sudan Grass is a very suitable indicator of phosphate deficiency, it fails as an indicator of potash deficiency.

Accordingly, during the fourth year (December, 1935 to May, 1936), Messrs. C. H. F. Walker and B. de L. Inniss reconsidered the possibility of obtaining an alternative indicator plant more generally applicable than Sudan Grass. They selected Hill Rice for detailed study, but their numerical results were vitiated apparently by the operation of an abnormal deficiency factor, suspected to be some rare element as yet not identified. This suspicion has naturally imparted a new trend to the experiments, and future work on the Mitscherlich method will have to be suspended until the significance of the rarer elements in plant nutrition, and the possibility of their deficiency in certain of the local soils under examination, have been explored.

In the succeeding article, Mr. B. de L. Inniss briefly states the underlying principles of the Mitscherlich method, and describes the technique employed in its application. He then discusses critically the contributions made by previous students at the College, and suggests lines for future work. Through lack of adequate facilities and funds, and because the progress of the work has been very discontinuous, owing to the fact that no whole-time officers have been available to carry on the experiments over a consecutive number of years, the results are somewhat unconnected and inconclusive. Nevertheless, certain definite and valuable information has been obtained, sufficient perhaps to justify the publication of this account at the present juncture.

(II) Introductory.

The Mitscherlich method of assessing the nutrient status of a soil is based on Prof. E. A. Mitscherlich's claim to have established a growth law applicable to all species of higher plants. This law was developed from an experimental study of the effects of single factors on the amounts of growth of a suitable plant under carefully controlled conditions. Mitscherlich has suggested a mathematical relationship which expresses the interconnection between certain nutritional factors and plant growth, which is actually a development of Liebig's Law of the Minimum. Liebig's law states that the productivity of a soil depends on the magnitude of that particular constituent of the soil, or that particular growth factor, which is present in least amount. Mitscherlich has modified this formula by the statement that the magnitude of the increase in yield produced by a given increase in the limiting growth factor is proportional to the decrement from the maximum yield which can be obtained by increasing that particular factor.

This statement may be expressed mathematically thus:—

$$\frac{dx}{dy} = C\,(A-y)$$

where $\frac{dx}{dy}$ is the rate of increase of yield produced by the growth factor x; A is the maximum yield which can be obtained by increasing x, and C is a constant, called the "effect factor", or

"efficiency factor", which varies with the particular growth factor under consideration, for example, nitrogen, phosphate or potash occurring in soil.

The equation, when integrated and applied to a given quantity (b) of any growth factor, may be expressed thus :—

$$b = \frac{\log A - \log (A - y_0)}{C}$$

where y_0 is the magnitude of the yield obtained when no addition of the growth factor under consideration is made. If the maximum yield, A, be expressed numerically as 100, the equation becomes :—

$$b = \frac{\log 100 - \log (100 - y_0)}{C}$$

where y_0 is now expressed as a percentage of A.

This general equation is believed by Mitscherlich to be true for all plants. Furthermore, since the "effect factors" (C) for the three important nutrient entities, nitrogen, phosphate and potash, may be experimentally determined once and for all, their numerical values may be introduced into the general equation, which may then be used to assess the magnitude of each particular growth factor (b) in terms of the yield obtained (y_0) under controlled conditions. In actual practice, standard pots are used for growing an indicator plant in the soil under consideration. Different replicated treatments are given to the soil, and sufficient water is periodically added to ensure adequate supply, without the risk of waterlogging or lack of aeration. Details of the actual technique are given below.

Unfortunately, the Mitscherlich equation cannot accurately be applied to the case of the nitrogen growth factor, since it has not been found possible to add sufficient nitrogen to obtain an exact measure of the maximum yield. Consequently, a supplementary equation has been suggested for use in assessing the nitrogen factor, namely,

$$A_N = \frac{Ky - y_0}{K - 1}$$

where y_0 is the yield obtained when no nitrogen is added to the soil, and $K = 10^{cx}$, where c is the nitrogen effect factor, and x is the rate of application of nitrogen.

Expressed in terms of the dimensions of the standard Mitscherlich pot, and the value of the experimentally-determined nitrogen effect factor, K, is numerically equal to 2.512, so that the supplementary equation becomes :—

$$A_N = \frac{2.512 - y_0}{2.512 - 1}$$

Here, y_0 may thus be expressed as a percentage of A_N, and the values obtained may then be substituted in the general equation.

In applying the Mitscherlich equation for assessing the magnitudes of the growth factors, nitrogen, phosphate and potash, the values for A (maximum yield when all the growth factors are present in optimum quantities) and for y_0 (yield when no addition of any one factor is made), may be determined by weighing the crop obtained in a series of replicated pot cultures of the soil under examination.

Effect Factors.

The values of the effect factors for nitrogen, phosphate and potash, as determined by Mitscherlich, are as follows :—

Factor.	Grams per Pot. (g/pot.)	Hundredweights per acre. (cwt./ac.)
Nitrogen ..	0.40	0.153
Phosphate ..	1.95	0.753
Potash ..	3.02	1.170

Subsoil factor.

In testing a sample of soil obtained from a field whose nutrient status is to be determined by the Mitscherlich method, the soil is usually taken down to an arbitrary depth (say 25 cm. or nearly 10 inches, which is the depth preferred by Mitscherlich). This procedure does not take into account the effect of the subsoil in the nutrition of the crop growing in the field; accordingly Mitscherlich suggests that the values for the amounts of phosphate and potash in the soil, as determined by a pot experiment, should be multiplied by 2. Since nitrate is usually leached downwards into the subsoil, and may therefore be more prevalent therein than in the topsoil, Mitscherlich suggests that another multiplying factor should be employed for translating the results for nitrogen content in the experimentally-examined soil sample into actual nitrogen contents in the field. He recommends that the magnitude of this subsoil factor be taken as 1.5 for permeable sandy soils, 2.0 for medium sandy soils or loams, and 4.0 for heavy clay soils.

The assumption of the constancy of the effect factor implies that the manurial requirements of all plants growing in a particular soil are identical, which is a very convenient and simple premise, but one which is open to severe criticism. Nevertheless, since the aim of the Mitscherlich method is to provide a measure of a soil's content of available nutrients, the manurial treatment of that soil in the field may be varied depending on the kind of crop to be grown, and on the resources of the farmer.

For indicator plant, Mitscherlich uses Oats. Since this plant is a long-day plant, and will not mature in the tropics, where the length of the daylight period is insufficient to induce flowering and fruiting, some other indicator plant must

be utilised. Sudan Grass (*Andropogon sorghum* var. *sudanense*) has been used with some success in Hawaii, but it is not altogether satisfactory, being much more sensitive to phosphate deficiency in the soil than to potash deficiency.

(III) Technique of the Mitscherlich Pot Test.

The standard Mitscherlich pot is a cylindrical white enamelled iron vessel, 20 cm. diameter and 20 cm. deep, having an 8 cm. drainage hole in the bottom. It rests on an enamelled iron stand which allows a moveable shallow cylindrical drainage-catchment saucer, 24 cm. diameter and 7 cm. deep, to be placed under the pot. A wire frame, 80 cm. tall, is provided to support the growing plants.

Generally, ten pots are used for each test. Three pots are filled with soil to which a complete (N P K) manure has been added; three pots with soil to which nitrogen and phosphate (N P) have been added; three with soil to which nitrogen and potash (N K) have been added, and one with soil to which phosphate and potash (P K) have been added. The manures are applied in the following kinds and amounts:—

Nitrogen;
Sulphate of ammonia, 1.0 gm. in 20 cc. water.

Phosphate;
Superphosphate, 1.1 gm. in 50 cc. water.

Potash;
Sulphate of potash, 1.5 gm. in 50 cc. water.

In addition, the following substances are supplied:
Sodium chloride, 0.5 gm. in 5 cc. water.
Magnesium sulphate, 0.5 gm. in 5 cc. water.
Precipitated chalk, 1.5 gm.

In order to facilitate drainage when heavy soils are to be tested, Mitscherlich recommends that pure quartz sand be mixed in equal parts with the soil under examination.

The pots are placed on benches inside a wire-screened shed to protect the plants from birds and the larger insects, and preferably moved periodically so as to reduce mutual shading.

Soil Sampling.

Mitscherlich advocates the use of a sampling spade, which cuts a column of soil 25 cm. deep and 6.5 cm. diameter. At least fifty cores should be taken at regular intervals within a field whose soil is to be tested.

The samples are bulked, air-dried, mixed, sifted through a 1 cm. sieve, mixed again, and stored until needed for testing.

Filling of Pots and Treatment during Growth.

The sand and soil are mixed in a large basin, and the solutions of the manures are added in the following order during the mixing:—

(*a*) No nitrogen, (*b*) No potash, (*c*) No phosphate, (*d*) Complete manure.

This procedure prevents contamination of the first three treatments by the complete manure mixture. The pots are appropriately filled, and then planted with grass seeds, employing for the purpose a marking board having 35 equally-spaced holes. A glass rod is used to make the cavities, $\frac{3}{4}$-inch deep, into which the seeds are introduced, two to each cavity. The pots are set up on the benches in the shed, and watering is begun.

If possible, distilled water is used, or if not obtainable in sufficient quantity, rain water. The amount of water added daily or twice a day is best ascertained by weighing each pot, and adding sufficient water to bring the soil nearly to saturation, but this procedure was not practicable at the College. The drainage water from each pot, which collects in the saucer placed below, is first added to the soil, and then the deficit is made up by addition of fresh water. When the seedlings have reached the second leaf stage, they are thinned out, so as to reduce their number to 35 for each pot. In due course, the crops are reaped when most of the plants in the complete nutrient cultures have ripened. The stems are severed at soil level, and each crop is cut into small lengths, dried in an air oven, and weighed. The recorded weights comprise the only experimental data needed. The mean results obtained from the four different treatments, namely, (*i*) complete manure, (*ii*) no potash (*iii*) no phosphate, and (*iv*) no nitrogen, are substituted in the Mitscherlich equation, and values are thus derived for the contents of available nitrogen, phosphate and potash in the soil under examination, as measured by their actual effects on the quantitative growth of the indicator plant. In practice, Mitscherlich uses specially-prepared tables from which the nutrient content of the soil may be directly ascertained for different graded yields.

(IV) Review of the Mitscherlich Investigations at the College (1932-36).

(A) The work described by Coombs and Milburn (2) in their dissertations for the Associateship of the Imperial College of Tropical Agriculture, Trinidad, began the local investigations in 1932.

(1) The first requirement was a suitable indicator plant. Only a limited number of standard Mitscherlich pots were at first available, so that the tests were mostly made in kerosene tins of dimensions 24 × 24 cm. by 35 cm. deep or about 20 litres internal volume (0.7 cubic foot). The following plant species were tested as regards their suitability as indicators. Sudan Grass (*Andropogon sorghum* var. *sudanense*), Finger Millet (*Eleusine coracana*), Italian Millet (*Setaria italica*), Rice (*Oryza sativa*), Maize (*Zea mays*) Sunhemp (*Crotalaria juncea*), Tomato (*Solanum lycopersicum*), Tobacco (*Nicotiana tabacum*) and Cotton (*Gossypium hirsutum*).

The Sudan Grass seed was obtained from the Agricultural Experiment Station, Texas, U.S.A., on the advice of Dr. D. A. Cooke of the Experiment

Station of the Association of Hawaiian Sugar Technologists (6). The strain, Texas No. 2448, was used throughout. The results obtained with this indicator plant proved to be the most satiafactory of all the plants tested. It grew uniformly and rapidly, and was not attacked by insect pests or fungous diseases. It showed two disadvantages, however, namely, the plants grew very tall and needed proper staking, and the seeds are very small, necessitating careful handling during sowing and thinning.

Rice proved to be a failure, mainly because of uneven germination of the sample of seed available, otherwise this plant seemed to offer considerable possibilities.

Maize was unsuitable, because of its large size, so that only three plants could be grown in each culture.

Tobacco was unsatisfactory, because the seedlings required shading, and the plants were subject to severe insect attack.

Tomatoes did not thrive under the imposed conditions; the plants were too large and failed to set fruit uniformly.

Sunhemp was useless for nitrogen determinations, because of the formation of root nodules.

Cotton suffered severely from Aphid attack, and the plants were too large.

The two remaining grasses, *Eleusine* and *Setaria*, formed very weak straw, and failed to tiller satisfactorily.

The individual tests showed great variation in the response of the different plants to the various manurial treatments applied to any particular soil.

(2) Six soils were examined, namely, Brasso Clay, Caroni poor alluvial loam, College cricket-field silt, Esmeralda alluvial loam, Torrecilla alluvial sand, and Las Hermanas alluvial clay, all of which occur in Trinidad. The numerical results obtained for the nutrient contents of these soils differed greatly for the different indicator plants, as the following selected data demonstrate.

Soil.	Indicator.	Nitrogen Content cwt./ac.	Phosphate Content cwt./ac.	Potash Content cwt./ac.
Brasso Clay ..	Sunhemp	..	1.5	2.3
Caroni Loam ..	Cotton	2.8	excess	3.9
Do. do. ..	Tomato	2.6	17.3	excess
Do. do. ..	*Eleusine*	2.3	10.7	excess
Do. do. ..	*Setaria*	0.7	5.0	7.4
Do. do. ..	Sudan Grass	0.8	5.0	excess
Torrecilla Sand ..	Sudan Grass	4.4	1.7	1.8
Esmeralda Loam ..	Sudan Grass	2.4	0.5	2.6
Las Hermanas Clay	Sudan Grass	20.5	0.9	2.2
College Silt ..	Maize	1.4	0.9	1.3

The variability of these results may partly be due to irregularity in watering, which was not carefully controlled. Certain of the soils (for example, the Caroni Loam) were diluted with sand, which may have exaggerated the effect of deficiency of certain of the rarer elements, which subsequent work demonstrated to be a reasonable possibility. Further, the water used was tap water, which was later found to contain appreciable amounts of soluble phosphate. The sand employed for diluting some of the soils was suspected of containing significant amounts of potash, but subsequent analysis showed that it contained only 0.00659 per cent. of total potash (K_2O), which is believed to be negligible in its effects on plant growth.

(B)—(1) During the next year, Miller and Ashby (3) attempted to evaluate afresh the Mitscherlich "effect factors", using Sudan Grass as indicator plant in pure quartz sand containing graded basal applications of nutrients, as well as the customary Mitscherlich dressings. Their results indicated that the suggested Mitscherlich effect factors do not apply in the case of Sudan Grass. The following data show that the actual amounts of nutrients found in the sand cultures do not correspond with the calculated amounts, assuming Mitscherlich's factors to be correct.

Sudan Grass.	Actual Content.	Found.	Ratio.
Nitrogen ..	0.78 gr.	1.044 gr.	1.34
	0.78	1.177	1.51
	0.78	0.829	1.06
		Mean ..	1.30
Phosphate ..	0.41 gr.	0.0836 gr.	0.204
	0.175	0.0322	0.184
	0.41	0.1145	0.279
	0.175	0.0365	0.209
		Mean ..	0.22
Potash ..	0.310 gr.	0.559 gr.	1.803
	0.113	0.316	2.796
	0.113	0.260	2.301
	0.113	0.266	2.353
		Mean ..	2.31

Consequently, Miller and Ashby suggested that the standard Mitscherlich effect factors should be mutiplied by the means of the ratios obtained by comparing the data for "actual" nutrient contents and for "determined" nutrient contents, as set out in this table, *i.e.*:—for phosphate, $1.95 \times 0.22 = 0.427$; for potash, $3.02 \times 2.31 = 6.99$, and for nitrogen, $0.40 \times 1.30 = 0.52$, (afterwards altered to $0.40 \times 1.65 = 0.65$).

The following criticisms may be advanced against certain of the conclusions reached by Miller and Ashby.

(*i*) The cultures were contained in kerosene tins, which were filled with a six-inch layer of gravel and a seven-inch layer of quartz sand. The gravel contained some schist stones, which may have contributed to the nutrition of the Sudan Grass crop, since this is notably deep-rooted.

(ii) The tin cultures each contained 1.76 times the weight of sand required to fill a standard Mitscherlich pot; hence the effect factor values were divided by 1.76, which may be admissible when results are calculated as grams per culture, although this depends on the ratio of areas and not of volumes, but not admissible when they are calculated as hundredweights per acre.

(*iii*) The argument on which the recalculation of effect factors is based appears to be faulty, inasmuch as it utilises a theory to modify an integral part of itself.

(*iv*) The employment of sand cultures instead of soil cultures in order to procure comparable yield data is unsatisfactory, mainly on the grounds that they may have been deficient in certain of the rarer essential elements, none of which was added, though the manurial salts used may have contained traces of some of them. Miller and Ashby admitted that their plants did not grow normally in the sand cultures.

(*v*) The availability of the added nutrient elements, nitrogen, phosphorus and potash, is probably different in degree and amount in sand cultures as contrasted with soil cultures.

(2) Miller and Ashby retested three of the soils previously examined by Coombs and Milburn, namely, Torrecilla Sand, Las Hermanas Clay and Caroni Loam, employing Sudan Grass as indicator. The new effect factor values were applied in calculating the nutrient contents of these soils, which were expressed as hundredweights per acre, involving the conversion factor, 1.76. When the results are recalculated on the basis of the surface area of a tin culture as compared with that of a standard Mitscherlich pot culture, the values derived from Miller and Ashby's results approach more closely to those obtained by Coombs and Milburn, as is shown in the following table.

Soil.		Coombs and Milburn.	Miller and Ashby.	Last recalculated.
		cwt. ac.	cwt. ac.	cwt. ac.
Torrecilla Sand ..	N	4.4	7.23	5.3
	P	1.7	0.63	0.7
	K	1.8	2.71	1.2
Las Hermanas Clay	N	2.2	4.32	3.4
	P	0.9	0.33	1.5
	K	2.2	7.18	3.1
Caroni Loam	N	0.8	2.65	1.9
	P	5.0	0.63	2.8
	K	excess	1.56	6.7

Although the recalculated data are closer to those obtained previously, the differences are still too large. In each case, nitrogen contents are higher in the second determination by approximately the same amount, namely, 1.2 cwt. ac. This may be due to the fact that the soils had been stored for nearly a year in an air-dry condition between the first and the second experiments, and nitrate may have accumulated in considerable amounts within this period.

(C) During the next year, Tidbury and McCreary (4) continued the work of Coombs and Milburn.

(1) They first attempted to obtain data for constructing accurate phosphate and potash growth curves for Sudan Grass, using *soil* cultures (not sand cultures), known to be particularly deficient in phosphate or in potash. The soils were first diluted with sand, in order to exaggerate the deficiencies, and increasing graded amounts of phosphate manure or of potash manure were added to the different cultures, together with the remainder of the ingredients involved in the Mitscherlich treatments. The proportionate amounts of phosphate and potash added in each series were 0, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$ and the whole of the requisite doses of these two manurial substances.

The growth curve obtained for phosphate increments was very satisfactory, indicating the logarithmic relationships necessitated by Mitscherlich's law, but the growth curve for potash was indefinite. Evidently the potash-deficient soil employed in these experiments still contained sufficient potash to satisfy the requirements of the Sudan Grass plants. In order to test this conclusion, the crops obtained in the potash series of cultures were dried, ashed, and chemically analysed. The results demonstrated that the potash content of the plants obtained by each treatment was proportional in magnitude to the amounts of potash added, though evidently not proportional to the amounts of growth produced. Thus Sudan Grass does not appear to be a satisfactory indicator plant for assessing the available potash contents of soils, although it seems to be suitable for assessing available phosphate contents.

Recent work in Hawaii has shown, however, that sugar-cane will thrive in soils which Mitscherlich tests, employing Sudan Grass as indicator, prove to contain inadequate amounts of available phosphate. Since one of the most promising applications of the Mitscherlich method lies in its possible usefulness in diagnosing nutrient deficiencies of sugar-cane soils (especially deficiencies of potash), much further work is needed before it can be claimed that the best indicator plant has been discovered, and the best technique has been elaborated for this purpose.

(2) The kerosene tin so far had been the standard equipment employed at the College, because of its cheapness as compared with the standard Mitscherlich pot. Accordingly, Tidbury and

McCreary next attempted to assess the nutrient status of a soil of known field reputation by means of Mitscherlich tests, both in kerosene tins and in standard pots. The results obtained are given in the following table :—

	Nitrogen.	Phosphate	Potash.
	cwt. ac.	cwt. ac.	cwt. ac.
Standard Pot	5.87	3.46	4.47
Kerosene Tin..	3.34	5.23	4.28

The data do not show very good agreement, except perhaps for potash. The differences were thought to be partly due to irregularities in watering. Nevertheless, in each case, the tests appeared to demonstrate that the soil is well supplied with all three nutrient ingredients, which agrees with field experience. The soil sample was actually taken from a field of the College Farm in which a manurial experiment on tomatoes indicated that the soil is uniformly highly fertile, as shown by the fact that different manurial field treatments gave no significant increases in yield as compared with no treatment (control plots). The experiment needs repeating with less fertile soil, to which different manures have been added in a series of plots growing a field crop.

(3) Although Sudan Grass had given early promise of its suitability as an indicator plant, the later experiments described above had raised considerable doubt as to its general applicability to the problem of assessing the nutrient status of tropical soils, especially sugar-cane soils. Hence Tidbury and McCreary further tested Swamp Rice as indicator plant, and in addition, a new plant, Buckwheat, which appeared to them to offer possibility of success. Mitscherlich tests with these plants on Torrecilla sandy soil gave the following results :—

Indicator.	Nitrogen.	Phosphate	Potash.
	cwt. ac.	cwt. ac.	cwt. ac.
Rice ..	8.46	8.40	5.28
Buckwheat ..	17.55	8.96	6.12

The figures differ widely from those obtained by Coombs and Milburn and by Miller and Ashby for this soil, although the phosphate and potash figures agree fairly closely. Buckwheat was not considered satisfactory on the results of this experiment ; the plants grew too big, and the seeds were set early and were readily shed ; the root system was very small and penetrated only to shallow depth. Rice, on the other hand, was considered to be the best indicator plant so far tested. It tillered well and produced a large root system, and it was not attacked by pests and diseases. Unfortunately, the plant showed marked photoperiodism, and failed to flower during the relatively long days of May and June, although it flowered profusely when planted in October or November, for harvesting in January or February.

(D)—(1) During the current year (1935-36), the most urgent need appeared to be the further testing of Rice as indicator plant. Accordingly, C. H. F. Walker and the writer (5) attempted to obtain growth curves for phosphate and potash with Hill Rice, following the procedure of Tidbury and McCreary who used Swamp Rice. The seeds were obtained from the College Department of Agriculture, and sown in standard Mitscherlich pots containing College Farm soils known to be deficient in phosphate and in potash respectively. The soils were first diluted with three times their weight of pure quartz sand. Unfortunately, many of the plants were severely attacked by the rice nematode *Anguillulina* (*Tylenchus*) *angusta*. Their appearance also suggested that they suffered in addition from deficiency of available iron, probably exaggerated by the high dilution of the soil with sand. Some improvement in their condition was actually obtained by treatment with an iron salt, but their recovery was not sufficient to render the experimental results reliable. In view of these observations, suspicions were aroused as to the validity of all the previous results obtained when sand had been employed for diluting the soils under tests, especially College Farm soil. The writer therefore recommends that a standard solution containing the requisite small amounts of all the more important rarer elements be systematically added to soils undergoing examination by the Mitscherlich method.

(2) An attempt was next made to obtain a growth curve for potash, using the same mixed soil and sand cultures that had been set up for testing Hill Rice. Sudan Grass was again tried as indicator plant. The yields obtained were so low that it was suspected that the limiting factor was the deficiency of some rare element, exaggerated by the high dilution of the soils with sand. No symptoms that could be attributed to the effects of insect pests or fungous diseases were noted, but the plants grew slowly, and developed unhealthy pale-green leaves.

(3) In order definitely to test the possibility of rare element deficiency operating as a limiting factor, another concurrent series of soil cultures was set up. The soil samples used were taken from two plots of the College permanent manurial experimental area, namely, those lacking potash and phosphate. The soils were mixed together and then diluted with three parts their total weight of sand. Seven pots were filled with soil and sand mixtures, to which an adequate dressing of lime had been added, and seven pots were filled with unlimed soil and sand. In each group, the individual cultures were treated with dilute

aqueous solutions of salts containing the following elements :—(1) no element, (2) iron, (3) manganese, (4) boron, (5) zinc, (6) copper, (7) all these five elements. The cultures were then planted with Hill Rice seeds. Many of the plants were eventually killed by nematodes, just as in the first experiment, so that no useful evidence could be obtained from this test. Later, the same cultures were planted with Sudan Grass, which is probably not susceptible to nematode attack. At the time of writing, the plants had not grown long enough to permit final conclusions to be made.

(4) Another experiment conducted during the year aimed at procuring data for establishing a numerical value for the subsoil factor for phosphate and potash. Small plots were laid out on the College Farm, and treated severally with complete manure, with nitrogen and potash, and with nitrogen and phosphate, each treatment being replicated five times. Concurrently, a Mitscherlich pot test was run on soil samples taken from the same area. Hill Rice was employed in each case as indicator plant. The plants growing in the field suffered severely from water shortage during the dry season, and their development was very irregular, so that the yield results obtained were valueless.

It is evident from the above account that the progress made at the College in the Mitscherlich investigations has not been very great, although much useful experience has been gained, in spite of the limited equipment available. The chief aim of future work should be to procure a completely satisfactory indicator plant. Other tropical grasses, such as Para Grass and certain similar indigenous pasture grasses, should be tried. The cage or shed might with advantage be furnished with a glass roof, and made properly insect-proof. A further supply of standard Mitscherlich pots is also needed. In view of the recent interest aroused in Trinidad as to the possibility of deficiency of the rarer elements operating as a limiting factor in certain types of soil, notably those utilised for sugar-cane production, a systematic study of this problem should be undertaken as an essential corollary to further Mitscherlich investigations.

(V) Acknowledgment.

Our thanks are due to Professor W. G. Ogg and Dr. A. B. Stewart, of the Macaulay Institute for Soil Research, Aberdeen, Scotland, for kindly offering suggestions and valuable criticism during the progress of this work.

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CARNAUBA WAX.

This valuable wax is used in the manufacture of polishes for motor cars, furniture, floors and shoes, in the preparation of carbon paper, and of a variety of moulded articles. It is derived from the leaves and buds of the palm, *Corypha cerifera*, which grows chiefly in north-eastern Brazil. The annual world production of carnauba wax is about 10,000 tons. The Brazilian industry has recently been graphically described in the September issue of *Industrial and Engineering Chemistry*, by Dr. J. V. Steinle, who made an aeroplane trip to Brazil for the purpose of studying the native methods of production.

The part of Brazil where the particular palm grows mainly consists of arid sandy alluvial plains. The dry season here is very pronounced and long, but the whole area is flooded during the wet season by torrential rains.

The carnauba wax palm bears fan leaves and grows slowly to 40 feet height. After ten years of growth, when the tree is only a few feet high, the leaves are cut by natives for the purpose of wax extraction. Not more than 20 leaves are taken in any one year from any one tree, and only the upper leaves are severed. Generally the tree is visited three times during a dry season. The youngest leaves are collected separately from the old leaves. They yield a paler kind of wax. After cutting, the leaves are dried in the sun for three days. This causes the waxy bloom to separate from the leaf surfaces. The dried leaves are then shredded or slit in a closed room by drawing them over a series of spike-like knives set in a bench. The material is then beaten by sticks, so that the powdered wax collects on the floor of the room. It is swept up daily and melted in another room in petrol tins placed over a fire. The molten wax is strained through cheese-cloth into another vessel, where it sets hard on cooling. The solid wax is finally broken into pieces for transporting to the market.

The yield of carnauba wax is variable, depending chiefly on the age of the tree. One leaf, on the average, yields about 5 grammes of wax; one pound of wax is obtained from five palms in one year; one native can handle about 1,000 leaves in a day. Plantation methods for studying the palm are being considered, and a better technique for separating the wax and of regulating its quality is being studied.

RECENT INVESTIGATIONS ON SUGAR-CANE AND SUGAR-CANE SOILS IN TRINIDAD.

III.—Effects of Manurial Treatment with Ground Limestone on Crop Quality and Yield of Commercial Sugar.

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Introduction.

An account is given in this paper of the effects of manurial treatment of acid soils with regularly increasing dressings of ground limestone on sucrose content of sugar-cane, on quality of sugar-cane juice and on yield to the acre of commercial sugar, under conditions which obtain in Trinidad. The investigations were spread over the period 1929-36 and were based on quantitative manurial experiments laid down in the field.

It is to be inferred from the early literature (1) that the presence of ample lime in the soil increases yield of sugar in that it leads to improvement in the quality of sugar-cane juice. With few exceptions (2) the relationship between lime status of soil and crop quality has been little subject to critical examination in recent years, and the views of the earlier workers still appear to be generally held. The data which have been accumulated in Trinidad, however, provide evidence that appropriate manurial treatment of acid soil with ground limestone leads to an increase in yield of commercial sugar but that its effects on crop quality can be beneficial or adverse according to circumstances.

Scope of the Investigations.

The investigations were such as to obtain measurements of *the effect of size of dressing of ground limestone on crop quality, i.e.*

sucrose in cane (pol. per cent. cane),
sucrose in the juice expressed from the cane,
dissolved solids in the juice (°Brix),
coefficient of purity of the juice,

and on yield of available 96° sugar to the acre, under moisture conditions very favourable, favourable and unfavourable to ripening.

The investigations were carried out on plant and ratoon canes. Size of dressing of ground limestone is expressed in terms of the lime requirement of the soil.

The Manurial Experiments.

The measurements were made, in the main, on canes from the plots of Experiments IV and V which have been described in previous issues of this *Journal* (3). Both experiments were laid down in the form of three 8 × 8 Latin squares. Both were reaped as plant canes in 1931, as first ratoons in 1932, as second ratoons in 1933 and again as plant canes in 1935. In both there are four manurial dressings with ground limestone, viz. :—

(i) nil,
(ii) one-half the lime requirement of the soil,
(iii) the lime requirement,
(iv) one-and-a-half the lime requirement,

which were applied before ploughing in 1929. In Experiment IV the lime requirement is 20 tons of ground limestone to the acre. In Experiment V it is 16 tons. In both experiments the four dressings of limestone are repeated with and without standard treatment with pen manure* thus making the eight treatments of the rows and columns of the Latin squares.

Measurements were also made on canes from the plots of two subsidiary trials, Experiments XIV and XV. Experiment XIV contained three series of plots. One series remained unlimed; the second series was dressed with 5 tons of ground limestone to the acre (half the lime requirement of the soil) before ploughing; the third series was dressed with ground limestone at the same rate after ploughing. This experiment therefore enables in addition measurement of the effect of time of application of limestone on crop quality. It was laid down in 1934 in the form of randomised blocks and was reaped as plant canes in 1936. Experiment XV was laid down in 1930 as a 4 × 4 Latin square. It was reaped as plant canes in 1932 and as first ratoons in 1933. Half the plots in each row and column were dressed to the acre with 10 tons of ground limestone, the lime requirement of the soil. The limestone was forked into the soil after ploughing.

The method of measurement of lime requirement of the soils of the experimental areas has been described elsewhere (4).

Technique of Sampling in the Field.

Experiment V.

This experiment was sampled as plant canes in 1931 and as first ratoons in 1932. On both occasions three complete stools were taken from each plot of one Latin square. The three stools from each plot were bulked to give 64 composite samples for analysis. The average weight of a composite sample in this experiment was 45 lbs. The total number of stools to the plot was 195.

Experiment IV.

One complete stool of first-ratoon canes was taken from each plot of two of the Latin squares in 1932. The 128 samples of cane thus obtained were separately analysed. The total number of stools to the plot in 1932 was 225.

* 20 tons of pen manure to the acre. This dressing was applied to the first crop of plant canes in 1929 and also to the second crop of plant canes in 1933.

Two complete stools of plant canes were taken from each plot of all three Latin squares in 1935. The two stools taken from any one plot were bulked to form a composite sample for that plot. The 192 composite samples were separately analysed. The total number of stools to the plot in 1935 was 300*.

Experiment XIV.

This experiment was sampled as plant canes in 1936. The method of sampling was identical with that used in Experiment V. The total number of stools to the plot in Experiment XIV was 300.

Experiment XV.

In 1933 all the first-ratoon canes from the unlimed plots of this experiment were bulked, and milled under commercial conditions in Caroni factory. A series of samples of the juice from the first mills were taken for analysis. A similar procedure was followed with the canes from the limed plots.

In all the experiments the stool samples were obtained either immediately before or during harvesting operations. In all cases the position within the plots of the selected stools was decided by random choice. The sampling operations for Experiments IV and XIV were in the charge of Mr. J. A. Potter of the Ste. Madeleine Sugar Co., Ltd. The sampling operations for Experiment V were carried out with the assistance of the Department of Sugar Technology of the Imperial College of Tropical Agriculture.

Laboratory Measurements.

In Experiments IV, V and XIV the plot samples were immediately transported to the laboratory and ground in small power mills.† In Experiments IV and XIV either the complete sample from each plot or representative canes from each sample were milled. In Experiment V the individual cane stalks were cut through their entire lengths into approximately equal halves and one of the halves of each stalk was discarded before milling (5).

The technique of measurement used in the laboratory was in accordance with the revised methods of chemical control for cane-sugar factories published in 1931 by the Association of Hawaiian Sugar Technologists (6). The total dissolved solids (°Brix) and the amount of sucrose in the extracted juice were determined, and the coefficient of purity of the juice calculated for each of the plot samples. The amount of sucrose remaining in the megasse was also measured and added to the sucrose content of the juice to give the total sucrose in each sample (pol. per cent. cane). The methods employed in the calculation of yield of commercial 96° sugar are described later in this paper.

The laboratory measurements were undertaken by the chemical staff of the Ste. Madeleine Sugar Co. in the case of Experiments IV and XIV, and by the staff of the Department of Sugar Technology of the Imperial College of Tropical Agriculture in the case of Experiment V.

The design of the field experiments and the technique adopted for sampling the plots enable the data obtained to be statistically analysed according to the methods of Fisher (7). The large number of replicate samples for the individual liming treatments (either 32 or 48 in Experiment IV and 16 in Experiment V) afford a high degree of accuracy to the examination of the relationship between size of dressing of ground limestone and quality of cane under the conditions which obtained.

Factors Influencing the Maturity of the Cane Samples.

Data for soil texture, variety of cane, age of cane and rainfall, *i.e.*, for factors which are of importance in influencing the degree of maturity of the plant and ratoon canes at the time of sampling, are summarised in Table I.

*When Experiment IV was replanted in 1933 a system of spacing the canes was adopted which differed from that used for the first planting in 1929.

† The efficiency of these small mills is approximately equivalent to that of the first mills of a commercial factory.

TABLE I.—*Factors influencing degree of maturity of the cane samples.*

Experiment.	Variety of cane.	Stage in crop series.	Age at sampling (months).	Soil type.	Rainfall before sampling (inches).			Conditions for ripening.
					Penultimate month.	Ultimate month.	Total for two months	
V ..	B. 156	Plants	20	Loam	0.44	1.54	1.98	Very favourable
IV ..	B.H.10(12)	Plants	18	Heavy clay	0.85	2.24	3.09	Favourable.
XIV ..	B.H.10(12)	Plants	17½	Clay-silt	10.64	3.45	14.09	Unfavourable.
V ..	B. 156	1st R.	13	Loam	1.24	7.39	8.63	Unfavourable
IV ..	B.H.10(12)	1st R.	13	Heavy clay	3.13	3.18	6.31	Unfavourable.
XIV ..	B.H.10(12)	1st R.	12	Clay-silt	9.35	3.68	13.03	Unfavourable

Soil Texture.

Partial mechanical analyses of the soils of the four experimental areas are recorded below. The soil of Experiment V contains sand in excess of the other constituents and approximates to a loam. Clay predominates in the soil of Experiment IV. The soil of Experiment XIV is a silty clay with a very small proportion of sand. That of Experiment XV contains sand, silt and clay in approximately equal quantities.

Experiment.	Sand.	Silt.	Clay.
V	40	27	22
IV	9	21	65
XIV	7	40	43
XV	31	34	33

Variety of Cane.

The variety of cane planted in Experiments IV, XIV and XV was B.H. 10 (12). In Experiment V it was B. 156. When mature the variety B. 156 tends to dry out more rapidly than B.H. 10 (12).

Age and Appearance of Cane at Sampling.

Plant canes are customarily harvested at the age of 16 to 20 months, and ratoon canes at the average age of 13 months, in Trinidad.

Plant canes.

The plant canes of Experiment V had an over-ripe appearance when sampled at the age of 20 months. Data obtained from the experimental area indicate that there was an average loss in yield of cane, due to drying-out, of at least five tons to the acre at the time of sampling.

The plant canes of Experiment IV were sampled when 18 months old. The canes had the appearance of maturity. A little dried-out cane was found on the experimental area.

The plant canes of Experiment XIV were sampled at the age of 17½ months. They appeared green and immature. No dried-out cane was found on the plots.

Ratoon canes.

The ratoon canes of Experiments IV and V were sampled at the age of 13 months.

The ratoon canes of Experiment XIV appeared green and immature when sampled at the age of 12 months.

No dried-out ratoon cane was found on any of the experimental areas.

Rainfall before Sampling.

Plant canes.

On the *comparatively light, loam soil* of Experiment V only 2.0 inches of rain fell during the two months and 1.5 inches during the month before sampling. Moisture conditions were therefore very favourable to ripening.

On the *heavy clay soil* of Experiment IV 3.1 inches of rain fell during the two months before sampling and 2.2 inches during the month before sampling. Moisture conditions on this area were favourable to ripening in spite of the heaviness of the soil.

Moisture conditions were unfavourable to ripening of the plant canes in the case of Experiment XIV. During the two months and the month before sampling 14.1 inches and 3.4 inches of rain fell on the *silty-clay soil* of the area.

The variations in rainfall during the critical months before sampling of the plant canes on the three grades of soil enable a measure of the effect of manurial dressings of limestone on the quality of the crop under circumstances very favourable, favourable and unfavourable to ripening.

Ratoon canes.

On the loam soil of Experiment V the rainfall during the two months and the one month before sampling was 8.6 inches and 7.4 inches, respectively. On the heavy clay soil of Experiment IV the corresponding figures are 6.3 inches and 3.2 inches. On the soil of Experiment XV they are 13.0 inches and 3.7 inches. *Rainfall was too heavy for moisture conditions to be favourable to ripening in any of the three experiments with ratoon canes.*

Effect of Size of Dressing of Lime on Sucrose in Cane.

PLANT CANES.

There are set out in Table II data relating to the effect of size of dressing of ground limestone, measured in terms of the lime requirement of the soil, on the amount of sucrose in plant cane (pol. per cent. cane) under the conditions which have been described.

No dried-out cane was included in the samples taken for analysis.

TABLE II.—*Effect of size of dressing of limestone on amount of sucrose in plant cane.*
(SUCROSE IS EXPRESSED AS A PERCENTAGE OF THE WEIGHT OF MILLED CANE.)

Experiment.	Variety of cane.	Age of plants at sampling.	Manurial treatment with limestone.				Conditions for ripening.
			Nil.	½ L.R.	L.R.	1½ L.R.	
V ..	B. 156	20 months	12.84	13.09	12.88	12.61	Very favourable.
IV ..	B.H.10(12)	18 months	17.00	16.86	16.96	17.02	Favourable
XIV ..	B.H.10(12)	17½ months	11.93	11.39	..	..	Unfavourable.

TABLE III.—*Effect of size of dressing of limestone on sucrose content of plant cane in the presence and absence of pen manure, under conditions very favourable to ripening. Variety B. 156.*

(SUCROSE IS EXPRESSED AS A PERCENTAGE OF THE WEIGHT OF MILLED CANE.)

Dressing of limestone.	Observed values.		Values calculated by formula.	
	Unpenmanured plots.	Penmanured plots.	Unpenmanured plots.	Penmanured plots.
Nil	12.89	12.79	12.92	12.81
½ L.R.	13.30	12.89	13.22	12.85
L.R...	13.07	12.69	13.15	12.73
1½ L.R.	12.76	12.46	12.74	12.45

Conditions Very Favourable to Ripening.

B. 156, plant canes, 20 months old.

The soil of the experimental area approximates to a loam. Rainfall was very light during the two months before sampling. The plant canes had an over-ripe appearance and there was an average loss in yield, due to drying-out, of at least five tons of cane to the acre.

The average amount of sucrose in the plant cane on the unlimed plots is 12.84 per cent. of the weight of milled cane. At the dressing of limestone equal to half the requirement of the soil of the experimental area the percentage of sucrose in cane rises to 13.09. At the full lime requirement the percentage falls to 12.88, a value approximately equal to that for the unlimed plots. At one-and-a-half the lime requirement there is a further fall in sucrose content to 12.61 per cent., a value below that for the unlimed plots.

This rise and subsequent fall in the percentage of sucrose obtained both for the plant canes on the unpenmanured and on the penmanured plots of the experimental area. The observed values for these two series of plots are recorded in Table III. In this table each of the observed values is a mean for eight replicate samples.

The relationship between size of dressing of limestone and amount of sucrose in cane for the unpenmanured and penmanured plots and for all plots is graphically illustrated in Figure I.

If the sucrose-limestone curves are represented by equations of the type $Y = A + B\xi_1 + C\xi_2$, the constants A, B, C and B/2C have the values set out in Table IV.

The constants B and C are statistically significant for the three series of plots. The data therefore pass the test necessary to establish the statistical significance of the rise and fall in sucrose content. *The conclusion that the sucrose content of the cane at first rises to a maximum and then falls to a lower value, as the dressing of limestone increases, may therefore be accepted with confidence.*

It is of interest that on this experimental area a similar rise and fall in yield of cane has been found to occur, under certain circumstances, as the dressing of limestone increases (3).

Values for the amount of sucrose in cane calculated by use of the formula $Y = A + B\xi_1 + C\xi_2$ are recorded in Table III. The calculated values are in remarkable agreement with the observed values for both penmanured and unpenmanured plots *i.e.*, the sucrose-limestone curves illustrated in Figure I approximate very closely to parabolic form.

TABLE IV.— *Values for the constants A, B, C and B/2C. (Figure I).*

Constant.	Unpenmanured plots.	Penmanured plots.	All plots.
A	13.006	12.710	12.856
B	−0.0605±0.0197	−0.119±0.027	−0.0905±0.0103
C	−0.179±0.022	−0.083±0.030	−0.1313±0.0115
−B/2C.. ..	−0.169±0.059	−0.72 ±0.176	−0.345 ±0.050
	≡0.67 L.R.	≡0.39 L.R.	≡0.58 L.R.

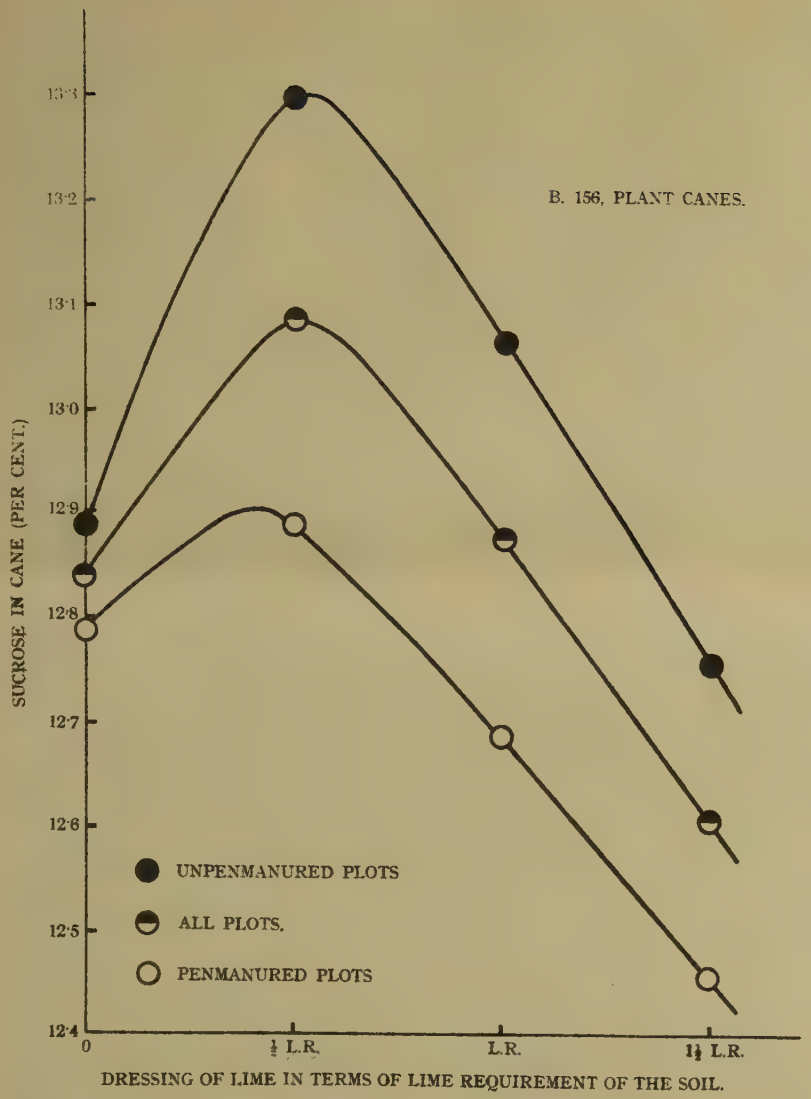

FIG. I.—EFFECT OF INCREASING MANURIAL TREATMENT WITH GROUND LIMESTONE ON AMOUNT OF SUCROSE IN CANE UNDER MOISTURE CONDITIONS VERY FAVOURABLE TO RIPENING.

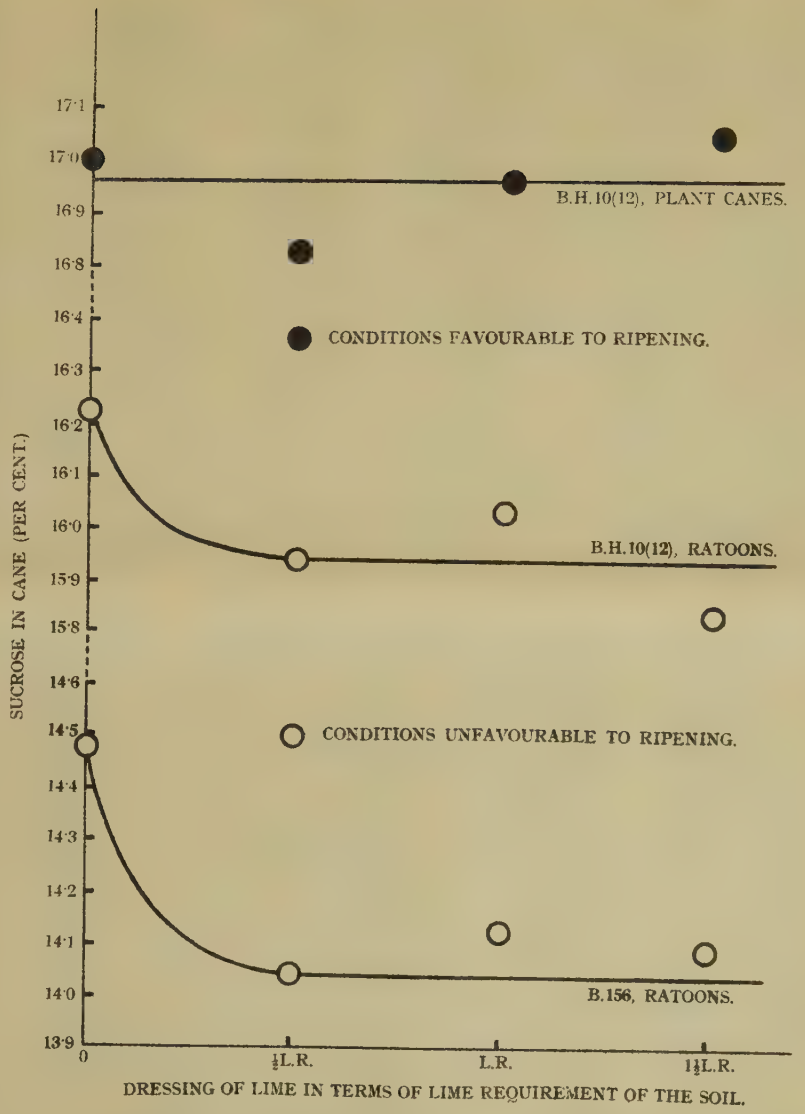

FIG. II—EFFECT OF INCREASING MANURIAL TREATMENT WITH GROUND LIMESTONE ON AMOUNT OF SUCROSE IN CANE UNDER MOISTURE CONDITIONS FAVOURABLE AND UNFAVOURABLE TO RIPENING.

An interaction with pen manure.

The average sucrose content of the cane on the plots without pen manure is 13.01 per cent. The average for the plots with pen manure is 12.71 per cent. The depression of 0.30 lb. sucrose per 100 lbs. of cane due to the dressing of pen manure is statistically significant.

By use of the constant B/2C it can be shown that the maximum point of the sucrose-limestone curve lies at 0.67 times the lime requirement of the soil of the experimental area for the unpenmanured plots and at 0.39 times the lime requirement for the penmanured plots. The difference between the values of B/2C for the two curves is 0.55 ± 0.18. This difference is significant, P being less than 0.05. It would seem, therefore, that *the dressing of lime associated with maximum sucrose is dependent on the basal manurial treatment, and can be significantly smaller in the presence than in the absence of pen manure.*

The maximum point of the sucrose-limestone curve for all plots, *i.e.*, irrespective of treatment with pen manure, can be shown to lie at 0.58 times the lime requirement of the soil in this experiment.

Sucrose in juice.

The curves for sucrose content of the juice expressed from the plant canes of both unpenmanured and penmanured plots of Experiment V show a significant rise and fall similar to that which obtains on the curves for sucrose content of cane. The sequence of values for the unpenmanured plots, as the dressing of limestone increases, is 15.56 lbs., 15.77 lbs., 15.66 lbs. and 15.44 lbs. of sucrose per 100 lbs. of juice. The corresponding sequence of values for the penmanured plots is 15.40 lbs., 15.45 lbs., 15.27 lbs. and 15.08 lbs. of sucrose. The maximum value for sucrose in juice on the unpenmanured plots can be shown to correspond to 0.64 (± 0.05) times the lime requirement of the soil, and on the penmanured plots to 0.28 (± 0.15) times the lime requirement. The values calculated by use of the formula $Y = A + B\xi_1 + C\xi_2$ are again in very close agreement with the observed values for the two series of plots. The values for B/2C are 0.22 ± 0.051 (unpenmanured plots) and 0.95 ± 0.15 (penmanured plots). The difference of 0.73 ± 0.16 is statistically significant.

The maximum value for sucrose in juice for all plots, irrespective of treatment with pen manure, lies at 0.52 times the lime requirement of the soil.

Results obtained elsewhere.

Williams and Follett Smith (2) record two experiments in which dressings of lime led to a significant increase in the amount of sucrose in cane. It is possible that the lime status of their plots corresponds to the rising portion of the curves illustrated in Figure I.

Conditions Favourable to Ripening.

B.H. 10 (12), *plant canes, 18 months old.*

The soil of the experimental area is much heavier in texture than that of the previous experiment. Rainfall was light during the two months before sampling. The canes, which were harvested when two months younger than the plants of variety B. 156, were mature in appearance. A small quantity of dried-out cane was found.

Manurial treatment with limestone, irrespective of the size of dressing, had no effect on the sucrose content of plant cane of variety B.H. 10 (12) *under the favourable conditions for ripening.* The amount of sucrose in cane on the unlimed plots attained the comparatively high value (for Trinidad) of 17.00 per cent.* The values for the limed plots are 16.86 per cent., 16.96 per cent. and 17.02 per cent., in order of the size of dressing. These values are means for separately analysed samples from 48 replicate plots. The average value for the limed plots is 16.95 per cent. The difference of 0.05 lb. of sucrose per 100 lbs. of cane, due to liming, is well within the range of experimental error.

The sucrose-limestone curve is recorded in Figure II.

Sucrose in juice.

The juice expressed from the plant canes on the unlimed plots contained 21.34 per cent. sucrose. The juice from the limed plots contained 21.19 per cent. sucrose. *The apparent difference due to liming is not statistically significant.*

Results obtained elsewhere.

Williams and Follett Smith (2) record examples in which no effect of manurial treatment with lime on sucrose value could be detected. Moisture conditions in their experiments may resemble those which obtained in Experiment IV.

Conditions Unfavourable to Ripening.

B.H. 10 (12), *plant canes,* $17\frac{1}{2}$ *months old.*

The soil of the experimental area is a silty clay. Rainfall was heavy during the two months before sampling. The canes were green and immature in appearance. No rotted cane was found.

The amount of sucrose in cane on the unlimed plots has the low value of 11.93 per cent. The amounts in the cane on the plots dressed with half the lime requirement of the soil before ploughing and after ploughing are 11.54 per cent. and 11.24 per cent. respectively. The effect of time of application of the dressing on amount of sucrose in cane cannot be established as statistically significant, but *the average depression of* 0.54 *lb. sucrose per* 100 *lbs. of cane, due to liming, approaches significance.*

The values for sucrose are means for six replicate samples in the case of the unlimed plots and 12 replicate samples in the case of each series of limed plots.

The immaturity of the plant canes at the time of sampling in this experiment is reflected in the low sucrose values.

*Compare the values recorded for plant canes of the same variety in the experiment which follows.

Sucrose in juice.

The sucrose content of the juice expressed from the cane on the unlimed plots is 14.96 per cent. The values for the plots dressed with lime before ploughing and after ploughing are 14.11 per cent. and 13.97 per cent., respectively. *There is an average depression of 0.92 lb. of sucrose per 100 lbs. of juice, due to liming. This depression might be due to chance far less than once in 20 times.*

RATOON CANES.

Conditions Unfavourable to Ripening.

There are set out in Table V data relating to the effect of size of dressing of ground limestone on amount of sucrose in ratoon cane (pol. per cent. cane) under moisture conditions unfavourable to ripening.

B. 156, first ratoons, 13 months old.

The amount of sucrose in ratoon cane of variety B. 156 on the unlimed plots is 14.48 per cent. of the weight of milled cane. The values for the limed plots, in order of increasing size of dressing, are 14.08 per cent., 14.12 per cent. and 14.09 per cent. Each value is a mean for separately analysed samples from 16 plots. The average depression of 0.38 lb. sucrose per 100 lbs. of cane, due to manurial treatment with lime cannot in this instance be established as significant.

The amount of sucrose in the juice expressed from the ratoon cane appears to fall continuously as the dressing of limestone increases, but the significance of the fall is statistically open to doubt. The sequence of values is 17.86 lbs., 17.56 lbs., 17.43 lbs. and 17.31 lbs. of sucrose per 100 lbs. of juice.

B.H. 10 (12), first ratoons, 13 months old.

The amount of sucrose in ratoon cane of variety B.H. 10 (12) on the unlimed plots is 16.22 per cent. of the weight of milled cane. The values for the limed plots, in order, are 15.94 per cent., 16.03 per cent. and 15.83 per cent. Each measurement is a mean for separately analysed samples from 32 plots. The effect of size of dressing of limestone on amount of sucrose in cane is not statistically significant. *The average depression of 0.29 lb. of sucrose per 100 lbs. of cane, however, might be due to chance less than once in 100 times.* This appears the earliest occasion for a depression in the amount of sucrose in cane, associated with rainfall conditions unfavourable to ripening, to have been definitely established as a consequence of manurial treatment with lime. The depression is smaller than that recorded for the ratoon cane of variety B. 156, but the estimate of statistical significance is based on a much larger number of replicate samples.

The values for sucrose in juice expressed from the ratoon cane of variety B. H. 10 (12) show a similar and significant depression due to liming. 100 lbs. of juice from the unlimed plots were found to contain 20.43 lbs. of sucrose. The value for the limed plots is 20.14 lbs. of sucrose per 100 lbs. of juice.

The relationship between size of dressing of limestone and amount of sucrose in ratoon cane (pol. per cent. cane) for the varieties B.H. 10 (12) and B. 156, under conditions unfavourable to ripening, is graphically expressed in Figure II.

B.H. 10 (12), first ratoons, 12 months old.

In this particular experiment the cane from all the unlimed plots was bulked and milled under commercial conditions, and samples of juice from the first mills were analysed. A similar procedure was followed with the cane from all the limed plots. The amounts of sucrose in 100 lbs. of juice from the unlimed and limed plots were found to be 18.09 and 17.37 lbs., respectively. Liming therefore caused a depression of 0.72 lb. of sucrose per 100 lbs. of juice. This is the largest depression of its kind which has so far been found to obtain in these investigations.

Other results.

A depression, due to liming, in the sucrose content of the juice of ratoon cane has been noted in Trinidad by Rodriguez (8).

Sucrose data have been recorded in this paper for one experiment on plant canes and three experiments on ratoon canes which were sampled after periods of comparatively heavy rainfall. In each the trend of the effects of liming lie in the same direction. *There appears to be little doubt therefore, that manurial treatment with lime can depress the amount of sucrose in cane and in juice when moisture conditions are adverse to ripening.*

TABLE V.—*Effect of size of dressing of limestone on sucrose in ratoon cane.*

VALUES FOR SUCROSE ARE EXPRESSED AS PERCENTAGES.

Experiment.	Variety of cane.	Age of ratoon at sampling.	Manurial treatment with limestone.				Conditions for ripening.
			Nil.	½ L.R.	L.R.	1½ L.R.	
V ..	B.156*	13 months	14.48	14.08	14.12	14.09	Unfavourable.
IV ..	B.H.10(12)*	13 months	16.22	15.94	16.03	15.83	Unfavourable.
XV ..	B.H.10(12)†	12 months	18.09	..	17.37	..	Unfavourable.

* Sucrose in cane. † Sucrose in juice.

Comparative Value of the Factors 'Sucrose in Cane' and 'Sucrose in Juice' for Investigational Purposes.

It will be recollected that small but efficient power mills were used to express the juice from the samples of cane in Experiments IV, V and XIV.

It can be shown that the limestone curves for sucrose in plant and ratoon cane, which are recorded in Figures I and II, are identical in kind with the corresponding curves for sucrose in the juice expressed from the cane. If a rise and subsequent fall is found to occur in the curve for sucrose in cane, it is repeated in the curve for sucrose in juice. The maxima of the curves for sucrose in juice correspond closely to the maxima of the curves for sucrose in cane. If the amount of sucrose in cane is found to be unaffected by manurial treatment with lime, then the amount of sucrose in juice is also unaffected. If dressings of limestone are found to have an adverse effect on the sucrose content of cane, they are also found to have an adverse effect on the sucrose content of juice. Even minor fluctuations, due to chance variation, in the curves for sucrose in cane, such as are evident in Figure II, are in general reflected in the curves for sucrose in juice.

The accumulated data therefore provide evidence that *the trend of the effects of manurial treatment on the amount of sucrose in cane can be reliably determined from analyses of the juice expressed from the cane by mills of the type used for these investigations,* and that measurement of the amount of sucrose in cane is not essential when such mills are used. This conclusion is of importance in that in many cases it eliminates the necessity for determination of the amount of sucrose in megasse, thereby enabling a considerable reduction in the routine laboratory work entailed by studies of the kind described in this paper.

(*To be continued.*)

SHALL CROPS BE ADAPTED TO SOILS OR SOILS TO CROPS?

Under this title, Dr. E. N. Fergus, Assistant Agronomist of the Kentucky Agricultural Experiment Station, discusses in a paper published in the *Journal of the American Society of Agronomy*, June, 1936, pp. 443-446, the *pros* and *cons* of soil improvement. He writes:—All efforts to obtain profitable production in farm crops involve either improving the adaptation of crops to the environment or improving the environment for the crop. Probably most farmers practise mainly one or the other, but few follow one to the exclusion of the other. There are many ways in which farm crops can be adapted to the environment, as, for example, by varietal improvement, choice of seed, seeding practices, choice of crop to suit soil-type, &c., but none is more generally followed nor more potent for good or evil to civilization than selection of crops to suit the soil's productive capacity. Environmental adaptation, likewise, is brought about in several ways; for example, by cultivation, drainage, irrigation, manuring, liming, and applying commercial fertilizers. Undoubtedly, the practices of the latter group, that most affect the well-being of society over a long period, are manuring, liming, and fertilizing.

To the farmer on a highly productive and relatively inexhaustible soil, the difference between farm practices based upon adapting soil to crop, on the one hand, and those based upon adapting crop to soil, on the other, is likely to be largely academic. But to society the difference is critical, because any soil farmed for several generations according to one of these practices will ultimately differ widely in productivity from a similar soil on which the other method of farming has been practised. Most, if not all, countries of northern Europe practice an agriculture based upon soil adaptation, whereas large sections of China and India may be considered to have emphasized crop adaptation as their basic agricultural practice, even though they have endeavoured to conserve the mineral resources their soils.

The advantages of a system of crop production based upon principles of building soil productivity to suit crops are familiar to all agronomists, and therefore need not be discussed. Probably all agronomists are more or less aware, also, that the practice of selecting crops adapted to successive degrees of soil depletion will eventually exhaust the soil and bring agriculture to ruin.

The outcome of the practice of choosing poor-land crops to suit a soil as it becomes impoverished, unattended by liming, manuring, and fertilizing, is certain to have serious consequences. For example, red clover once regularly produced excellent crops on land in Kentucky on which even adapted varieties will not now grow without lime and phosphorus. Instead of applying these materials to the soil, farmers use crops adapted to poorer soil. Redtop, orchard grass, and especially lespedeza are used. They require less calcium and phosphorus than clover; lespedeza at least, also seems able to obtain appreciable amounts unavailable to clover and other crops. Consequently, it seems that sooner or later the supplies of calcium, phosphorus, and other essential elements must become so much reduced that they are no longer sufficient.

Again, poor-land crops, when grown on poor soil, yield crops of low quality. They are frequently very weedy, especially the forage crops. No crop so far discovered has quite equalled certain weeds in adaptability to poor soil. But more serious is the low quality of the crop itself. It reflects the poverty of the soil on which it grew.

The significance of the low nutrient content of the poor-land crop becomes apparent when the many reported instances of malnutrition of animals that have been traced to mineral-deficient forage are considered. Most of these have been reviewed by Orr, and all are pertinent to the question of the nutritional value of poor-land crops, but especial significance is found in the results of studies of malnutrition of native cattle on native ranges in Florida.

It will be recalled that two types of malnutrition were found in the slow-growing native herds, one caused by a deficiency of calcium in the forage, the other by a deficiency of phosphorus. The actual difference between the composition of the herbage on the affected and the healthy ranges was small.

The low nutritive value of poor-land crops grown on poor soil has a still more serious aspect, however. The human being is just as much dependent upon his food for minerals as the lower animals. Therefore, it is to be suspected that mineral malnutrition must likewise occur in peoples dependent upon food grown upon impoverished soil for their sustenance. While information pertaining to human malnutrition that may be ascribed to this cause is meagre, there is enough to indicate that it exists in serious proportions. According to Maxwell, osteomalacia is common in women living in northern China and Manchuria. Many of the cases are caused by a deficiency of calcium in the native food plants, *i.e.*, crops adapted to soils that are now deficient in minerals because of the long practice of a system of farming that has not provided for the return of minerals to the soil in amounts equal to those removed in crops. The manifestations of the disease were identical with those of the same disease in the native cattle of Florida, namely, as a skeletal breakdown most common in females that had borne offspring.

It should be emphasized that while a system of farming based principally upon growing poor-land crops appears wholly unsound as a permanent agricultural practice, it must not be assumed that its limited utilization is to be condemned. There are large areas of eroded and worn-out land on which the growing of poor-land crops, while building them into productive soils, is a practice well suited to the requirements, resources, and abilities of the farmer-occupants.

Agronomists assume a grave responsibility in recommending even limited use of poor-land crops, at least on poor soils. The practice is so easy to follow that the farmer will continue it until both he and his soil are impoverished beyond redemption by his own resources. Therefore, while it may appear at times to be our duty to recommend crops suited to poor soils, it is even more our duty to point out the consequences of the improper use of this system of farming, and to insist that, unless it contributes permanently to soil building, it is unprofitable to the farmer and to society.

REVIEWS.

AN OUTLINE OF MALAYAN AGRICULTURE. Compiled by D. H. Grist, *Dept. Agric. S.S. & F.M.S.* Kuala Lumpur, 1936.

The Malayan agriculturist is very fortunate in the literature of his natural resources, and indeed many others having no direct concern in the Malay States will have found cause for gratification in the sources of information relating to tropical development supplied by past and present officers of that Colony. Only recently Dr. Burkhill published his encyclopaedic "Dictionary of Economic Products of the Malay Peninsular", which has been acclaimed on all sides as a work of the highest and most permanent merit. The present volume has been published by the Department of Agriculture with a view to providing the "planter and agriculturist, the student, the administrator, and inquirers in search of general knowledge" with a summary of agricultural information and advice which hitherto have been scattered in the numerous bulletins and pamphlets issued by them from time to time. This is a complete Outline of Malayan Agriculture owing authority to the specialised knowledge of the compiler's colleagues both in and out of the Department from whom he has frequently sought the subject matter required. It replaces the earlier "Handbook of Malayan Agriculture", issued in 1922, by an up-to-date text-book of wider scope than its predecessor. The student, particularly, will find the references, conveniently placed at the end of each chapter, a most useful starting point for further investigations into more detailed subjects than the book is able to treat.

The book is divided into six parts devoted to Agricultural Conditions, Agricultural Practice, Major, Secondary and Minor Crops, and Stock. The earlier chapters will be of special interest to other tropical colonies and those concerned with administrative problems. There will be found a good generalised account of the agricultural industries, the land tenure systems operating in the different States, marketing conditions, and the historical development of the Department's policy towards native production and education.

The crop section of the book is naturally the largest, and describes on standardized lines the major and secondary crops of the colony in considerable detail. Costs of production, cultivation methods, varieties, preparation for market and the diseases and pests of these crops all receive adequate attention. Rubber, coconuts, rice, oil palms and pineapples come under the category of major crops. For some of the less important crop plants the relevant information chosen for inclusion sometimes lacks an essential feature, as for example in the description of the Papaw (*Carica Papaya*) where no mention is made

of the fact that the plant is unisexual. A large number of economic plants come in for cursory treatment as "minor crops" under the headings of spices, cereals, oil-yielding crops, fibres, drugs, and miscellaneous. Considering the very wide field covered, the crops are very fairly described according to their economic importance, and the clearly sub-divided chapters and sections will help much to give proper perspective to the topics discussed. Mention should also be made of cover and green-manure crops whose true place in agricultural practices, particularly of perennial crops, is recognised by a good account of soil treatment and management in an earlier section.

The concluding section on Stock deals in turn with Cattle, Pigs, Poultry, and Freshwater fish in a manner which does justice to a very important if rather backward branch of tropical agriculture. Many of the topics here discussed, such as questions of rations and pasture management, have an application in all parts of the humid tropics, so that this section should be carefully and widely read.

This volume is entirely a local production. It is well printed and illustrated with eighty-six photographs of a generally high standard. In short, it is one of the most attractive textbooks on tropical agriculture (even though its purpose is to serve a particular region) which has appeared in recent times. Full credit goes to the Department of Agriculture, and in particular to Mr. D. H. Grist, the compiler, for its clear and serviceable lay-out.

N. W.

* * *

THE USE OF FERTILIZERS.

By A. S. Barker, *Oxford University Press*, London, 1935. pp. 204, price 7*s*. 6*d*.

In a foreword to this book, Professor J. A. Scott Watson, of Oxford University, stresses the fact that important changes in the fertilizer industry, and in the business of crop production have occurred in recent years, necessitating the partial or complete abandonment of traditional methods for improving soil fertility (such as crop rotation, sheep folding, and the use of dung), and the extension of farming in Great Britain so as to include the large-scale growing of remunerative crops formerly considered as belonging solely to the garden. The newer types of concentrated chemical manures (for example, nitrate of potash and phosphates of ammonia), and the cheaper grades of nitrogenous manures produced by air-fixation methods, have created the possibility of an almost unlimited expansion in the use of artificial manures. The whole subject of manuring therefore requires new treatment, and such is afforded it in this book, though mainly from the point of view of the British agriculturist.

Mr. Barker's main object is to present technical knowledge of artificial manures in its economic and practical implications for the use of farmers, vendors of manures and agricultural students, especially in relation to those crops where data established by scientific experiments are not available. After the general ideas of plant nutrition have been introduced, the different types of manures—nitrogenous, phosphatic and potassic—are described in turn, consideration being given both to artificial and to natural and organic manures. A chapter is next devoted to mixed and compound manures, and another to handling and storage. Three chapters following concern methods of application of manures, valuation and purchase, and the economics of manurial utilisation. The last chapter, occupying about one-third of the book, furnishes a guide to the manuring of temperate farm crops, including roots, cereals, forage, grass, vegetables and fruits.

The book skillfully avoids discussion of controversial theoretical aspects of nutrient soil relationships, and appears to be essentially sound in most of its statements. The subject matter is attractively presented, and the text is very readable. The common-sense outlook of the writer is to be commended, but the reviewer would have liked to have noted greater stress given to the fundamental relationships of soil and manure, since manuring first of all affects the soil, and then the modified soil affects the growing plant, though not always entirely beneficially. This aspect of manuring appears to be especially important in the growing of tropical crops, for in the tropics, striking deficiencies of one or other of the main nutrient elements are frequently revealed when the soil is examined by laboratory and field experimental methods. Nutrient "balance" thus assumes especial importance in tropical agriculture, and the use of "hard and fast" manurial formulae, designed to supply the often presumed requirements of specific crop plants is to be discouraged, unless detailed knowledge has first been acquired regarding the exact nutrient status of the particluar soil or soil-type it is intended to plant with a particular crop.

F. H.

* * *

VEGETATIVE PROPAGATION OF TROPICAL AND SUB-TROPICAL FRUITS.

Compiled by G. St. Clair Fielden, B.A., Imperial Bureau Fruit Production, Technical Communication No. 7. *Price* 2*s*.

Propagation of plants, either by rooting or grafting methods, is never likely to be completely standardized owing to the many and variable conditioning factors which control these processes. There are of course a number of prescribed and fairly widely recognised methods of technique, and an account of these is given, with excellent illustrations by line drawings, in the first part

of this Communication by R. J. Garner, N.D.H., Dip. Hort. Sci., in which he defines the terms in common use. But the fact remains that for any one locality modifications must usually be devised to suit the particular circumstances of soil, rainfall and topography if complete success is to be achieved. Especially is this so in the tropics where a high humidity and a temperature encouraging rapid vegetative growth create an environment which is totally different from that obtaining in temperate countries whence most of the original methods emanated. Exception to this may be cited in the so-called Forkert method of budding, originated by the Dutch in Java to meet their own needs in that direction, which is now being tried out on an increasingly large scale. Other tropical countries are beginning to awake to the urgency of carrying out their own experimental work, and at least to give the old methods extensive commercial trials.

The principal object of the Communication has been to summarize from reports widely scattered in many publications the results of trials of the various propagation methods with Tropical and Sub-tropical fruits, and to note such modifications of standard practice as have proved their utility. It may be said at once that the compiler's object has been achieved with great thoroughness; what little information has not for reasons of length been included or dealt with extensively may readily be found by reference to the full list of 123 texts at the end of the publication. Arranged alphabetically under the scientific name of the fruit, data are recorded under such headings as "Budding", "Rootstocks", "Etiolation", "Offshoots", &c., where details of practical procedure are described with commendable economy of words. The scope of the work has been limited to fruits, with the exception of Citrus to which a special Technical Communication (No. 3) was devoted in 1932, but it is gratifying to learn that a similar bulletin covering the perennial tropical and sub-tropical crops other than fruits is in course of preparation.

The subject is ostensibly of great moment to tropical crop husbandry—Sir Geoffrey Evans, C.I.E., M.A., in a Foreword indicates very clearly the vital significance which standardization of our fruit crops may have for tropical development—and the Imperial Bureau of Fruit Production has duly given to it an impressive and useful contribution for which horticulturists will be very grateful.

N.W.

* * *

A SHORT HISTORY OF THE GOLD COAST.

By W. E. Ward, M.A., B.Litt. *Longmans Green & Co.*, London, 1935, pp. 241, price 3*s.* 6*d*,

This book has been written primarily to meet the need for an inexpensive yet authoritative work on the subject indicated in the title, and is intended for use in schools. As described in the Preface it is "almost entirely a book of political history, of tribal movements, wars and treaties, and the rise and fall of states; there is very little social or constitutional history".

The subject matter throughout has been treated in an impartial and objective manner which is particularly pleasing; the style is terse and lucid, and is well suited to the swift action of the account. The chief literary sources consulted are listed in the Preface while evidence obtained by the author from various tribal authorities has been utilized in addition. It is clear from the text that the available data have been examined critically, and the limitations of hypotheses and points of disagreement between various statements are discussed adequately and without pedantry. The general arrangement is chronological, though, on account of the number of interacting factors, a certain amount of retrogression has been found necessary at various points. This has not appreciably interrupted the main sequence of events, and the whole account, which is brought up to January, 1935, is very readable.

Apart from its didactic value, this epitome of Gold Coast history will undoubtedly appeal to those who are interested in the subject but have little opportunity to peruse longer and less accessible works.

R. G. F.

* * *

IMPERIAL BUREAU OF PLANT GENETICS: PLANT BREEDING ABSTRACTS, SUPPLEMENT II.

Another good service has been rendered by the Bureau, in addition to its normal abstracting duties, in the publication of this supplement, which is described as a "Summary of Reports received from stations in the British Empire, 1932-1935". Describing the work begun or in progress by the various Departments of Agriculture, and research institutions in the Empire, it covers the same ground and follows similar lines to Supplement I which dealt with foreign countries.

The amount of labour involved in collating over 400 reports is considerable, and the Bureau is to be congratulated in employing its machinery to this useful end. Tropical as well as temperate economic plants are treated (herbage plants alone excepted), and a short section on the genetics of plant parasites is also included. The information has been conveniently arranged under crops, with subsections for each of the countries concerned. This should prove a most helpful publication for the practical plant breeder, especially where he is without the facilities of a large reference library.

N. W.

ERRATA.

Stock Rearing in the Tropics.

Page 151, *line* 29, Col. 2: For teaspoon *read* tablespoon.

Page 152, *last para.*, Col. 1: (6 ozs. turpentine in 20 ozs. linseed). Does not imply actual dose but proportions in which dose is mixed.

Page 152, *line* 17, Col. 2: For 12 *read* 24.

Page 153, *last para.*, Col. 2: *Omit* "Animals that appear . . . trypanosomiasis".

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Plot Technique in the Testing of Sugar-Cane Varieties. *By C. G. Lennox and A. J. Mangelsdorf.*

In the testing of new cane varieties, a first question is that of suitable plot size. It has been shown both in Hawaii and in Java that the error of the individual plot decreases as the plot size is increased. For light crops of 50 tons per acre 1/15 to 1/20 acre may be satisfactory, but 1/10 or 1/5 acre is preferable for 75 ton crops. A reduction in plot size with corresponding increase in number of plots may reduce the average error, but if this principle is carried too far, the result may be entirely misleading. For instance, H. 109 is a cane of relatively slow growth in the early stages, but in the end may give as much as 15 tons of sugar per acre in 24 months; on the other hand, U.D. 110 has great growth vigour in the early stages, but its final yield is considerably below that of H. 109. When these two varieties are tested side by side in small plots, U.D. 110 starts off quickly and maintains its lead throughout the crop, due to the fact that its strong roots invade the soil of its rival (border effect), whereas if the plots are large enough to minimize the border effect, the inherent superiority of H. 109 comes to the front.

For testing seedling canes, of which only a small supply of planting material is usually available, the authors prefer a systematic layout, in which the seedling plots alternate with plots of the standard variety, and they discuss at length the reasons why this arrangement is preferable to the Latin Square or randomized system. They also take occasion to discount the view held in some quarters that the technique which gives the lowest calculated error and thus the highest odds is necessarily the one to be preferred. High odds cannot in themselves insure against incorrect and misleading average differences, due to soil heterogeniety and border effects.—(*Facts about Sugar*, Vol. XXXI, No. 4, p. 150, 1936.)

* * *

Sugar Boiling Systems. *By J. H. Pratt.*

In the first part of this paper, the author discusses the various systems of sugar boiling that have been in more or less general use in Hawaii during the past few years. In the second part, he analyses data of about 30,000 strikes from several factories in three of the islands. From this analysis it appears that several of the Hawaiian factories show a decided tendency to lower the purities of their massecuites, particularly the "A" strikes. While some boil these "A" strikes at a purity only one or two points lower than that of the syrup (thick juice), others allow this difference to become 8 or 9 points, and any advantage that the latter may have from a high purity syrup is lost. The amount of massecuite that must be handled by the latter is seriously increased. Part of this drop of the purity of the massecuite is due to the emphasis that has been put on reducing the purity of the waste molasses, which is so often accompanied by a reduction in the purity of the low-grade sugar. There is an increased amount of inversion caused by in-boiling, and an increase in viscosity due to continued reprocessing of low purity products. These tendencies may perhaps be explained by the increase (20 per cent.) in amount of cane ground per hour during the past ten years, without a corresponding increase in the boiling house equipment to handle the additional material. Any method of boiling which increases the amount of material to be handled is therefore an additional handicap to already crowded equipment.—(*Facts about Sugar*, Vol. XXXI, No. 4, p. 146, 1936.)

* * *

Molasses Investigations and Treatment of Low-Grade Massecuites. *By W. L. McCleery.*

This is a progress report (the third) on heating of low-grade massecuites prior to purging at approximately the saturation temperature. All but five of the Hawaiian factories now have equipment for heating at least a portion of their massecuite. The trend is towards independent heaters over the centrifugals, the cone shaped ends being preferred. For controlling the saturation, use is made of the "saturoscope". About 12 to 15 sq. feet of heating surface per cu. ft. massecuite per hour are required. Temperatures of purging range from 90° to 120°F. The general object is to increase the massecuite density and the minimum temperature of purging, and yet obtain the same final purging viscosity. Experience confirms the conclusion that the highest density of boiling, compatible with crystallizer and purging equipment, will give the lowest purity molasses.—(*Facts about Sugar*, Vol. XXXI, No. 4 p. 145, 1936.)

* * *

A Method for the Biochemical Study of the Juice of the Cane Plant. *By Kozo Suzuki and Minoru Ishii.*

Sucrose and reducing sugars, the authors state, can be satisfactorily determined by the Hagedorn and Jensen micro-chemical method, using only a few drops of juice. A small piece of stalk, about 1 cm. square and 0.5 c.m. deep, is cut from the middle of the internode, and the expressed juice used for the sugars and refractometric dry substance. If the piece of stalk which has been operated on be at once sealed up well with lard or the like, infection is effectively prevented. Working in this way the authors have examined the variation of the sugars in different parts of the stalk during its period of growth.—(*Inter. Sugar Journal*, Vol. XXXVIII, No. 452, p. 310, 1936.)

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

Rainfall and Cotton Yields in the Sudan Gezira, *by E. M. Crowther and F. Crowther.*

Summary.—The relationships between seasonal yield and weather fluctuations for cotton grown under irrigation in the Sudan Gezira were analysed for periods up to 23 years. The analysis confirmed the generally recognised bad effects of high rainfall about the period of sowing cotton, but showed that this effect was not universal. An unsuspected but apparently general effect was discovered. Cotton yields were negatively correlated with the amount of early—May and June—rainfall. In some areas, yields were negatively correlated with late rainfall and with the total rainfall in the preceding year. The differences between areas in their responses to weather could be partially interpreted in terms of their situations and agricultural histories.

The progressive decline in yield at the oldest trial farm could be largely accounted for by a significant increase in total rainfall during the period of cotton cultivation. The total annual rainfall in the Sudan Gezira exhibited a significant seven-year periodicity, which was reflected in cotton yields, dura exports, and recorded famines. It happened that the first trial of irrigated cotton and the first use of the Sennar Dam, coincided with minimal rainfalls on this periodicity. The early promise and rapidly increasing difficulties may well have been due in part to the recurrence of unfavourable weather conditions, and not necessarily to soil deterioration and pests.

Uniformly-treated record areas could easily be established on a normal commercial basis in irrigation projects under central control, and would provide valuable material for research in agricultural meteorology, and a surer background for determining both experimental and commercial programmes. — (*Reprinted from "Proceedings of the Royal Society of London"*, Series B, No. 809, Vol. CXVIII, pp. 343-370, September, 1935.)

* * *

Soil Fertility Studies with Mauritius Soils.—*By N. Craig.*

The author notes that, although soil fertility is one of the most important subjects in the realm of agricultural science, and one in which a tremendous amount of work has been done, there is surprisingly little agreement as to the best methods to be employed. This is, perhaps, because different workers are engaged on very varied soil types. He therefore doubts whether standardized methods, applicable to all soil types, will ever be evolved. However, he offers an outline of methods used in Mauritius, which include field experiments, chemical laboratory methods, and physiological methods in field and laboratory, with chief emphasis on field experiments which should be supplemented with chemical and physiological tests. Phosphate fixation and the matter of exchangeable bases should be duly considered. Chief among the physiological methods studied was the analysis of juice. Some authors have stated that 0.03 per cent. of P_2O_5 in the ripe cane juice may be taken as indicative of a sufficient supply in the soil but that this figure is not universally applicable is shown by the fact that different cane varieties, grown under identical conditions and replicated as many as 36 times, may show very marked differences in their P_2O_5 content.—(*Facts about Sugar*, Vol. XXXI, No. 4, p. 149, 1936.)

* * *

Cellulose Sponge made from Wood and Cotton Pulps.

A cellulose sponge, peculiarly adapted to use in chemical, biological and other laboratories, is now available. It is made of cellulose obtained from highly purified wood and cotton pulps. Incidentally, it may be noted that the manufacture of this sponge opens a new outlet for produce of the soil as raw materials for chemical products. The sponge-like construction is obtained through chemical reactions. During manufacturing processes, the sponge material is refined and thoroughly sterilized, washed and dried. The sponge is the first of its kind to be made in the United States of America, although a similar product originated in Europe several years ago. Advantages of the "synthetic sponge" over natural sponge for laboratory use include its greater durability, resistance to dilute acids and organic solvents, and its extremely great resistance to alkalies. The sponge may be thoroughly sterilized by boiling in water, or by the use of steam.—(*Agricultural News Letter*, issued by E. I. du Pont de Nemours & Co., Vol. IV, No. 7, p. 89, 1936.)

* * *

Synthesis of Vitamin B_1 (Antineurin).

Since the realization that the molecule of vitamin B_1 contains two heterocyclic rings, a substituted pyrimidine and a substituted thiazole, intensive research has been directed towards establishing the positions of the substituent groups and the method of combination of the two rings. Prof. Williams and his collaborators at Columbia University have now succeeded in isolating a compound which is chemically and physiologically identical with the natural vitamin. Several groups of workers in Great Britain and Germany have been working at the same problem, but they will doubtless be among the first to congratulate the American chemists concerned on a brilliant and important piece of organic synthesis. It may be noted that this achievement means that, with the syntheses of ascorbic acid, lactoflavin, vitamin D and vitamin B_1, four vitamins have now been produced from completely inactive organic reagents by purely chemical means.—(*Nature* Vol. CXXXVIII, No. 3487, p. 356, 1936.)

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observation is assumed. Unless otherwise stated the prices quoted are spot, London.*]

SUGAR.—Prices on the Home Markets have ranged as follows (c.i.f. per cwt.)

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
27th August	4	6	8	3
3rd September	4	6	8	3
10th September	4	5¼	8	3
17th September	4	5¼	8	3
24th September	4	2½	7	11¼
1st October	4	3¾	8	0¾
8th October	4	4½	8	0½
15th October	4	6	8	3
(*17th October*, 1935)	5	0	8	9

With dull conditions prevailing and business in raw sugar practically at a standstill prices have remained almost unchanged. The undertone of the market, however, is steady.

* * *

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian F.G.F. Sakel.*
28th August	6.70	10.28
4th September	6.70	10.31
11th September	6.99	10.74
18th September	6.98	10.24
25th September	6.73	10.15
2nd October	7.02	—
9th October	6.85	—
16th October	6.99	—
(*18th October*, 1935)	6.40	8.88

Traders are still confused by the raw cotton situation but an upward movement in prices is expected as weather advices from the American belt have not improved. The crop is being adversely affected by heat and dryness while supplies this season will probably be much smaller than consumption. A limited business has been done in West Indian Sea Island, mainly at from 19*d.* to 20*d.*

* * *

COFFEE.—The market has been quietly steady with demand centering on cheaper sorts of African and East Indian. Jamaicas continue to sell well, the top price for the first fortnight in September being 213*s.* per cwt. Costa Rica quoted from 45*s.* to 54*s.* per cwt., Santos Superior 40*s.* 6*d.*

* * *

BANANAS.—The demand has been fairly good but prices for Jamaicas to wholesalers have been lower at £18 5*s.* per ton delivered London and £18 nearest station Provinces. Brazilians are £1 per ton higher at £16 delivered nearest station.—(From the *West India Committee Circular* 24th September.)

RUBBER.—Quotations for plantation sheet have ranged as follows:—

	Pence per lb.
26th August	7 5-8
2nd September	7 11-16
9th September	7 5-8
16th September	7 11-16
23rd September	7 11-16
30th September	7 13-16
7th October	7 7-8
14th October	7 15-16
(*16th October*, 1935)	6 1-4

The sequence of weekly declines in United Kingdom stocks which has been continuous for twenty-six weeks has recently been broken but it is anticipated that stocks are bound to decline further in view of the very small shipments from producing countries. American consumption for August at 46,656 tons is rather below some estimates. The market has been steady with prices a shade higher.

* * *

COPRA.—The market has been firm with an improved demand and gradually rising prices. West Indian f.m.s. quoted at £15 10*s.* c.i.f. London.

* * *

LIME PRODUCTS.—*Lime Oil.* There is no change in Handpressed which remains slow of sale at 35*s.* per lb. ex wharf. Sellers of Distilled continue to ask 22*s.* 6*d.* per lb. ex wharf, *Lime Juice.* There is no demand for Concentrated and Raw is quiet and unchanged at 2*s.* to 2*s.* 6*d.* according to quality.—(*West India Committee Circular*, 24th September.)

* * *

COCOA.—The cocoa market is developing into a very tight and serious situation, as the buying of spot and nearby Cocoas, particularly Bahias, has made dealers cautious, as they can make no replacements whatsoever in Brazil. They are also reluctant to sell the future positions of Bahia until they receive more assurance from the Primary Port that their contract will be filled and within contract time. Incidentally, the Bahia crop is practically sold, and, therefore, no pressure can be expected from there at any time this year. New crop Accra is offered at 34*s.* 3*d.* c.i.f. and locally $12.25 per fanega is paid.—(*By courtesy of The Cocoa Planters' Association of Trinidad, Ltd.*)

Note.—Since the above was written the break up of the gold bloc has influenced the sugar and rubber markets, bringing considerable activity to the former. The immediate effect on the rubber market was to cause a slight depression which, however, was short lived, prices closing higher. The cotton market took the devaluation news calmly.